HUNTING FOR EXOPLANETS

HOW IT WORKS

SCIENCE … TRAN… …RY

DISCOVER THE REAL **WILD WEST**

THE SKIES OF TOMORROW, TODAY!

FLYING CARS

HOW THE LATEST CONCEPTS COULD FINALLY MAKE SCI-FI TRAVEL A REALITY

+

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How your internal army defends against diseases

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ISSUE 104

WELCOME

The magazine that feeds minds!

WELCOME TO THE WILD WEST

“The Old West was famed for robberies and banditry, gunslingers and law enforcers. It was an exceptional time”

The real Wild West, page 64

Meet the team…

Charlie G
Production Editor
As Brad Pitt’s ‘Wardaddy’ so neatly summarises in the gory WWII hit *Fury*, ideals are peaceful, history is violent. Meet some of the most murderous dictators in history on page 72.

Charlie E
Staff Writer
Discover the story of Henrietta Lacks and her immortal cells on page 80. She is a true unsung hero of science, and her HeLa cells have contributed to many advancements in medicine.

Duncan
Senior Art Editor
I like a gadget or two, something that will make my life easier, especially round the house! So head over to page 54 to find out how to smarten up your home.

Laurie
Studio Designer
With the Jurassic Coast just on my doorstep I find it fascinating to learn how Mother Nature carved some pretty impressive land marks! Flick to page 24 to find out more.

FOLLOW US… How It Works magazine @HowItWorksmag

“Roads? Where we’re going, we don’t need roads!” cried Doc in *Back to the Future*. But 2015 came and went and sadly we very much do still need roads. Unlike the vision of the then-future in *Back to the Future Part II*, we still don’t have hoverboards or flying cars, but that could soon change. Several companies, including Uber, Boeing and Airbus are investing in the technology to make this sci-fi dream a reality. Finally. Fly on over to page 12 to learn more.

If you’ve watched films like *The Good, the Bad and the Ugly*, *The Magnificent Seven*, or (you guessed it) *Back to the Future Part III*, and wondered if life in the Old West really was that wild, then head over to page 64 to find out.

Also this month, we’ve got two guest authors. Biologist Catherine Carver tells us all about the weird and wonderful world of our immune system, while JAXA scientist Elizabeth Tasker takes us on an interplanetary journey to explore some incredible exoplanets. Enjoy the issue.

Jackie **Jackie Snowden**
Editor

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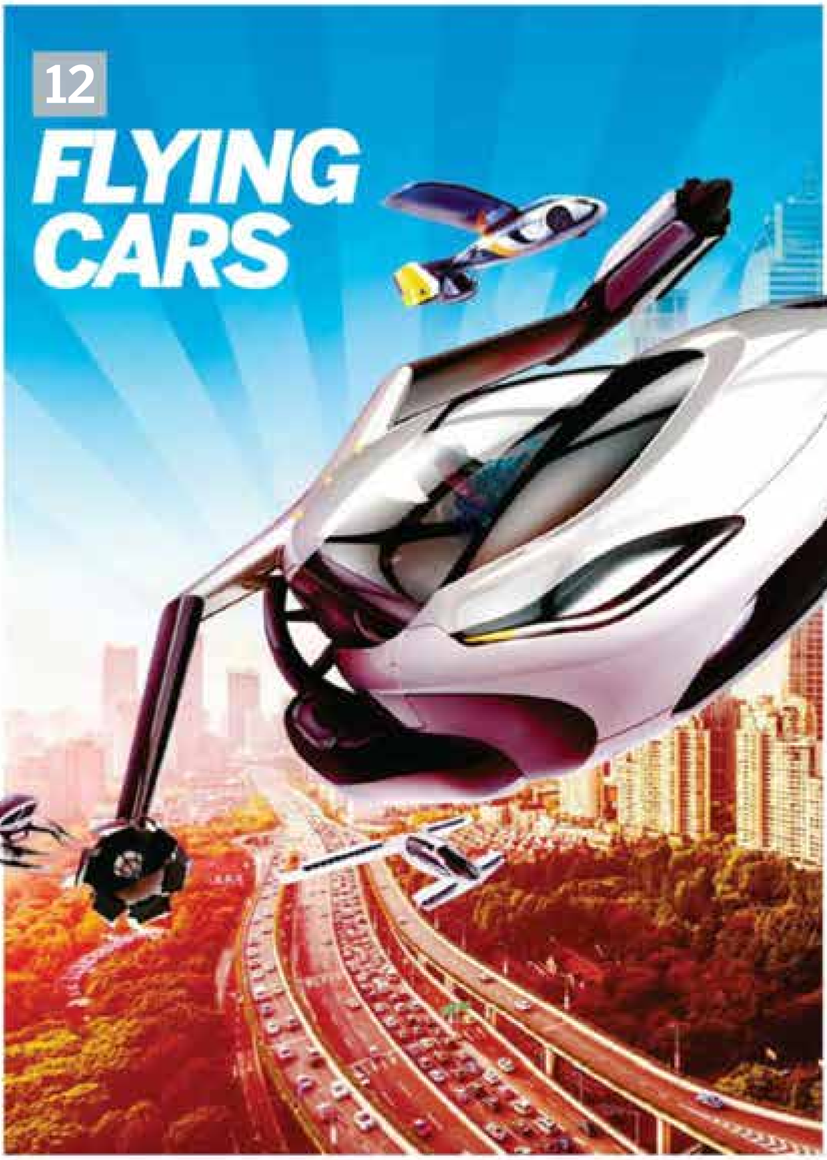

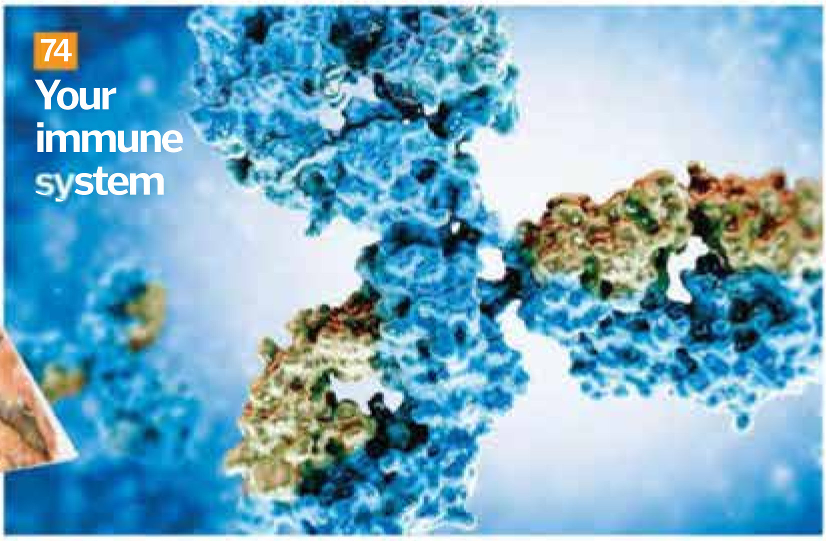

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- WILDLIFE OF THE CANYON LANDS
- ROSETTA THE COMET CHASER
- RED ARROWS & BLUE ANGELS

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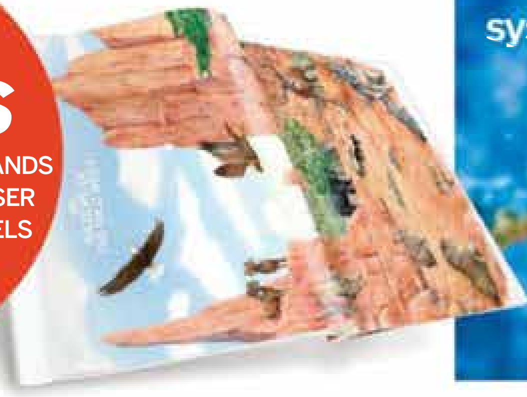

Meet the experts...

Jack Parsons
Editor of our sister magazine **All About History**, Jack takes a break from studying the past to turn his attention to the future. How will flying cars revolutionise travel? Find out in our cover feature on page 12.

Becca Caddy
Tech expert Becca explains how a myriad of smart home devices will not only make us safer, but also improve our wellbeing. From sleep monitors to security apps, and smoke alarms to air purifiers, discover more on page 54.

Jo Stass
This month, Jo explains how the first immortal cell line, taken from Henrietta Lacks, became one of the most important discoveries in the history of medicine. The 'HeLa' cells have helped to create vaccines and study diseases.

James Horton
James takes a trip to the wild, Wild West to separate fact from fiction in this period of American history that is so often romantisiced in films. Find out how people really lived during this time in our history feature on page 64.

Laura Mears
Reusing plastic bottles may seem like the eco-friendly option, but is it hygienic? Laura explains it all over on page 82. She also investigates the role of body salts, and the tech hiding inside a seemingly simple golf ball.

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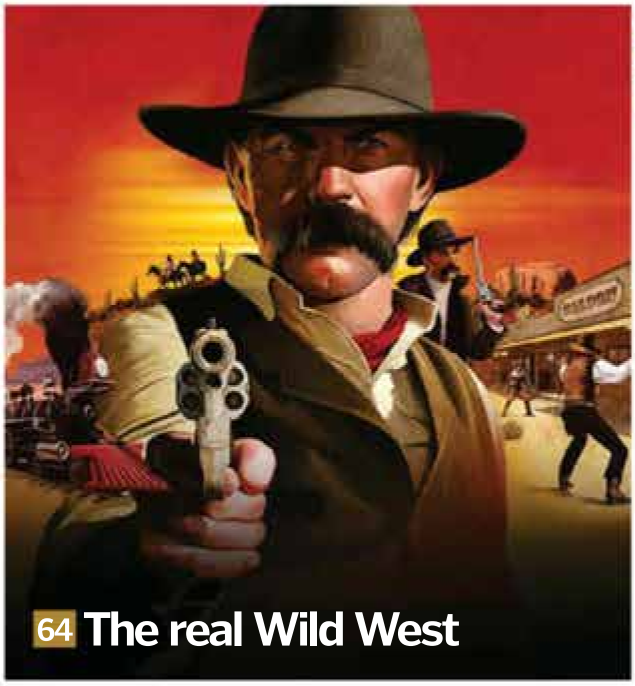
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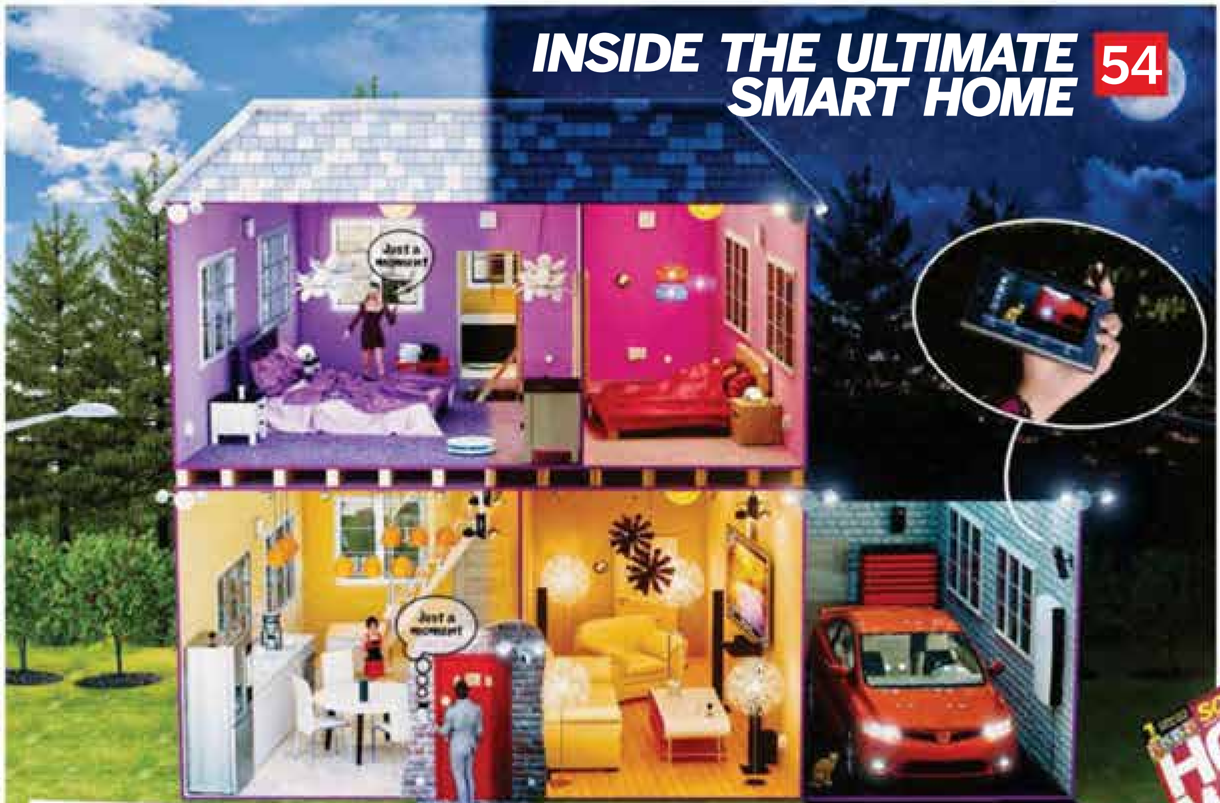
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Just a moment!

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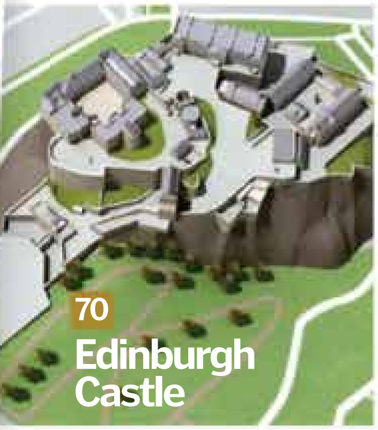
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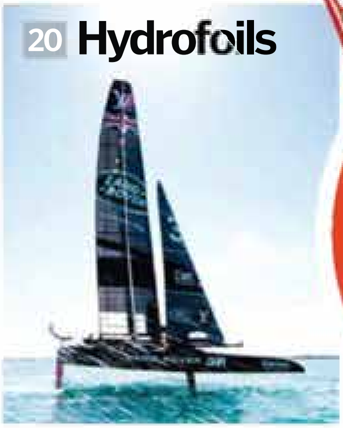
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Trappist-1 planets might have water

The outer planets of the newly discovered system may contain oceans on their surface

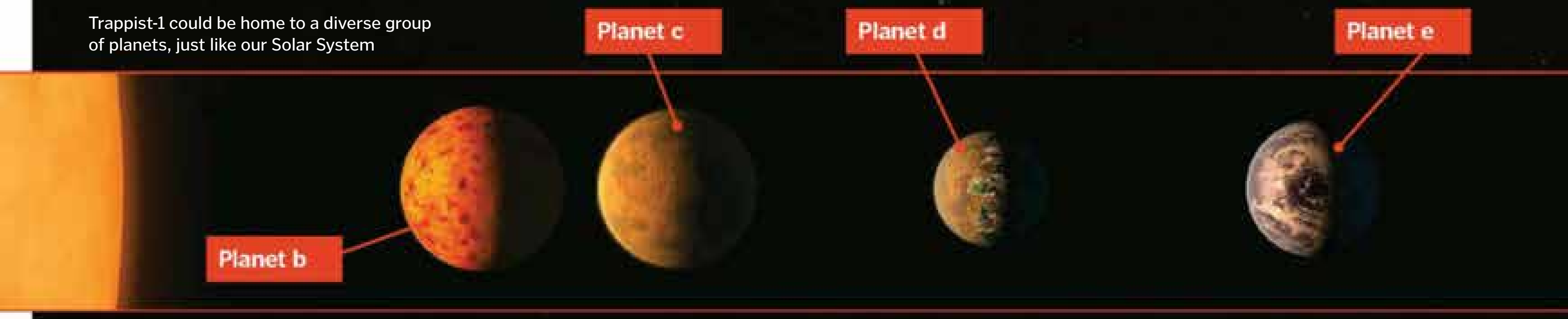
The Trappist-1 system, which lies 40 lightyears away and is composed of seven roughly Earth-sized planets orbiting a cool dwarf star, has taken another step toward solidifying itself as our Solar System's most exciting neighbour.

Our local star is responsible for almost all life on Earth, but it also constantly emits lethal radiation that could eradicate life and boil oceans. Fortunately, we're protected from most of these harmful rays thanks to our planet's thick atmosphere, but the planets in the Trappist-1 system may not be so fortunate.

Scientists using the Hubble Space Telescope recently analysed the UV radiation emitted by the Trappist-1 star to see the damage it inflicted on its orbiting planets. The inner planets have likely received enough radiation to have lost 20 times more water than all of the Earth's oceans combined over the past 8 billion years, mainly due to their incredibly close orbits. The outer planets, however, which drift inside the 'goldilocks zone' — where the temperature is just right for liquid water to exist — may have lost less than three of Earth's oceans worth.

If these planets have retained large volumes of liquid water, it could signal that life, however primitive, may be lurking in the system.

Trappist-1 could be home to a diverse group of planets, just like our Solar System



Radiation from the Trappist-1 star has likely caused the inner planets to lose all their water

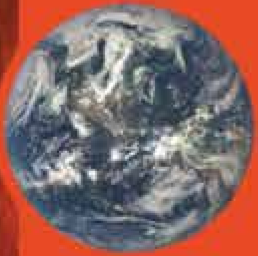
" XXXXXXXXXXX XXXXXXXXXXX XXXXXXXXX"

What type of planets are in the Trappist system?

Class I
These planets have no atmosphere, just like the Moon or the planet Mercury. It's likely that the inner planets of the Trappist-1 system all belong in this category.

Class II
These planets have atmospheres but no established lifeforms to interact with the gases and fluids, such as on Venus. It's possible that a Trappist-1 outer planet may be a Class II.

Class III
A thin biosphere sustains some biological activity, which may have been the case on Mars long ago. If this exists on a Trappist-1 planet, there may be primitive life there somewhere.



Class IV
A thick biosphere supports and is changed by the organisms that live within it, like on Earth. It's doubtful that a planet like this exists in the Trappist system.

Class V
An enhanced species living within the biosphere operates in a way that is beneficial to the organism and the atmosphere. We've yet to know of any planet, including ours, where this exists.

© NASA; ESA

Despite being mostly free from natural dangers, natural selection continues to shape our genomes

HUMANS ARE STILL EVOLVING

Our species continues to evolve by natural selection, but not in the way you might expect

A mammoth study that used data from 215,000 individuals has suggested that disadvantageous alleles are becoming less widespread in human populations, meaning that humankind is still adapting and tweaking its genome. To acquire these fascinating findings researchers focused on genetic changes occurring across just one or two generations and tested 8 million common mutations to identify any evolutionary change.

Interestingly, they discovered only two significant examples of mortality-causing gene variants that become less common with age. The authors claimed that this low number showed most gene variants that cause death later in life have already been removed by natural selection, which posed an interesting quandary. A genetic change that is only useful in a person's later years — after a typical individual has produced offspring — should be null and void in an evolutionary sense, as they have survived long enough to pass on their genes.

But with these findings new life has been breathed into the 'grandmother hypothesis', a theory that believes survival into old age, which allows for more years of caring for children and grandchildren, ultimately helps the next generation's survival. Secondly, the results also suggest these fatal, age-related mutations may have an affect earlier in life, albeit a subtler one.

Removing unwanted genes

The study identified two gene variants that caused significant differences in survivability within the APOE and CHRNA3 genes. The mutated version of APOE has been strongly linked with Alzheimer's disease and was rarely found in women over 70. And the mutant allele of CHRNA3, which is associated with heavy smoking in men, was identified less often in males who survived to middle age. Individuals without these mutations were deemed to have higher evolutionary fitness. If the authors are correct, these two variants will be something our descendants need not worry about, as natural selection will eventually remove them.

Unfavourable variants of APOE and CHRNA3 are likely being selectively ousted from our genomes

NEWS BY NUMBERS

18 months

Average amount of time between solar eclipses on Earth

300 kph

Hurricane Irma's maximum sustained wind speed

500 pages

Length of a mathematic proof used to solve the ABC conjecture

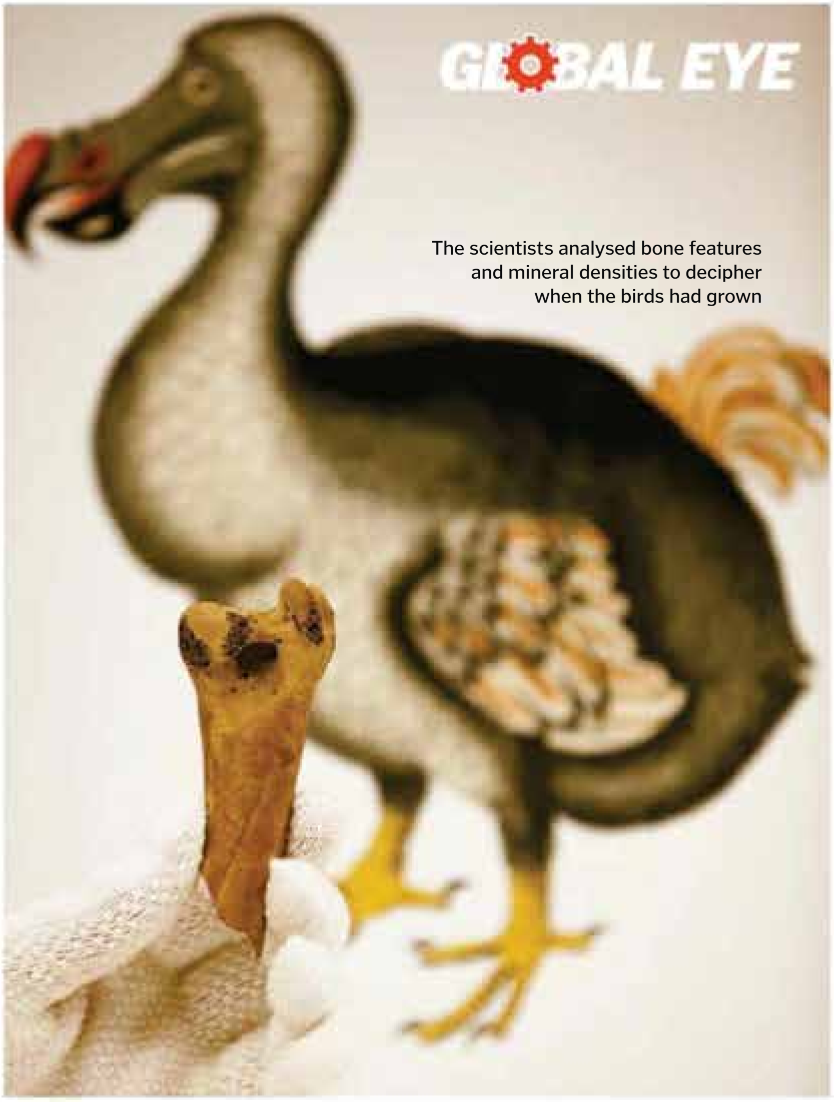
25°C

Highest temperatures observed in caves hidden under Antarctica's ice

What was life like for a dodo?

Bone specimens have provided a new insight

Modern bone histology techniques have provided a glance into the past of a species that's been extinct since the 17th century. By examining a set of 22 bones and assessing weather patterns of the dodo's habitat of Mauritius, scientists were able to build a month-by-month guide to being a member of the species. A lack of bone development correlated with the summer cyclone season and immediately afterward, during times of suspected moulting. These findings helped to establish that August was spent breeding, hatching occurred in the spring, and the summer was spent enduring the harsh conditions.



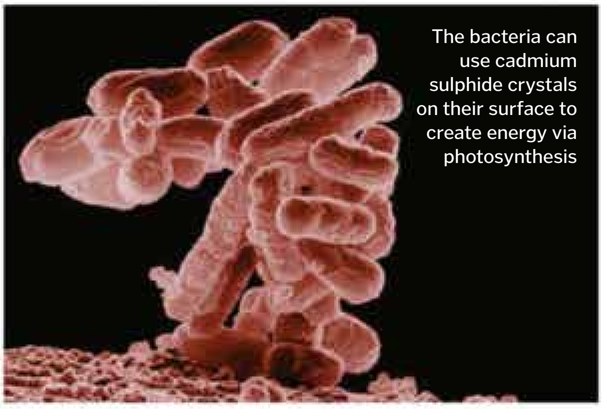
The scientists analysed bone features and mineral densities to decipher when the birds had grown

Box jellyfish may destroy our oceans

These greedy predators could ruin delicate marine ecosystems if water levels become too acidic

To discover the future consequences of carbon dioxide dissolving in our oceans, scientists at the Utah State University studied copepods — tiny crustaceans that sustain large and important food webs. Samples of these organisms were captured and half were placed in ambient seawater, while the other half were placed in water that had been acidified to levels predicted for 2100. When a natural predator, the box jellyfish, was added, they were observed to be particularly ravenous in the acidified water, where the copepods were feasted upon significantly more.

Acidified water would lead to over predation by box jellyfish and less copepods in our oceans



The bacteria can use cadmium sulphide crystals on their surface to create energy via photosynthesis

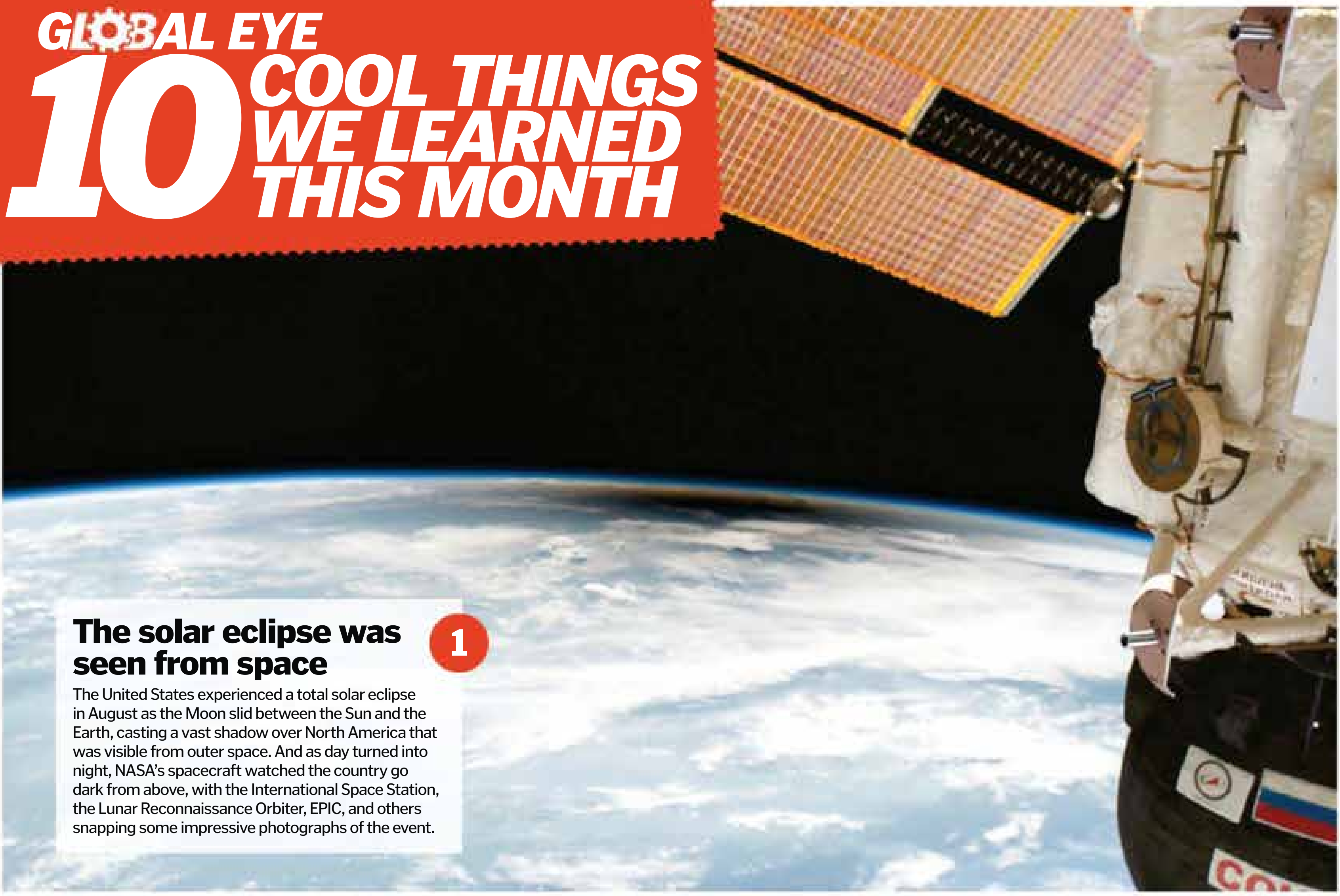
Cyborg bacteria create a green fuel source

Researchers equip bacteria cells with mini 'solar panels' for artificial photosynthesis

Scientists at Harvard University have created bacteria that are even more efficient at harvesting sunlight than plants. In a pioneering experiment, the team introduced the metal cadmium and observed as it was changed naturally by the bacteria into cadmium sulphide crystals. These tiny 'solar panels' formed clusters on the cell's surface and began acting as semiconductors, allowing the bacteria to efficiently photosynthesise, just as other bacteria and plants do in nature. A fuel ingredient, acetic acid, was a byproduct of the reaction.

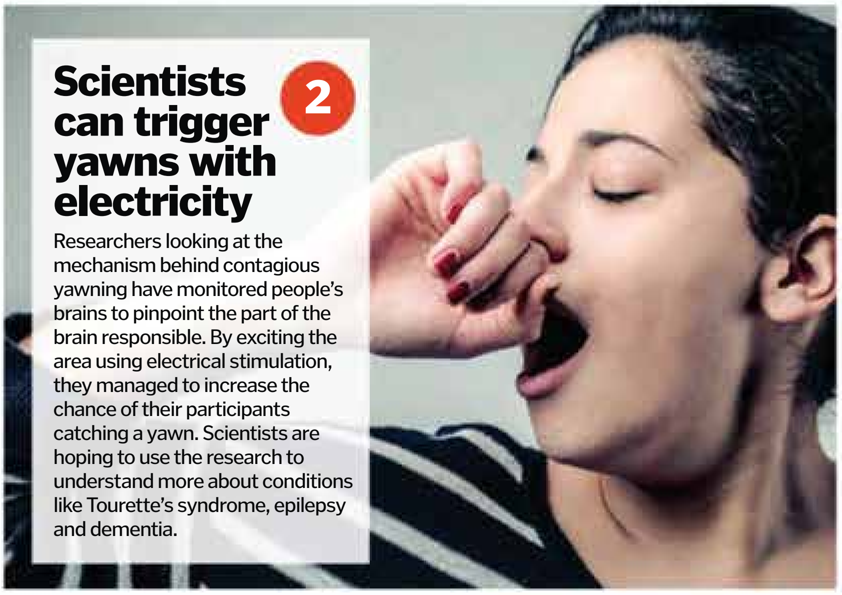
© Thinkstock; Getty

10 COOL THINGS WE LEARNED THIS MONTH



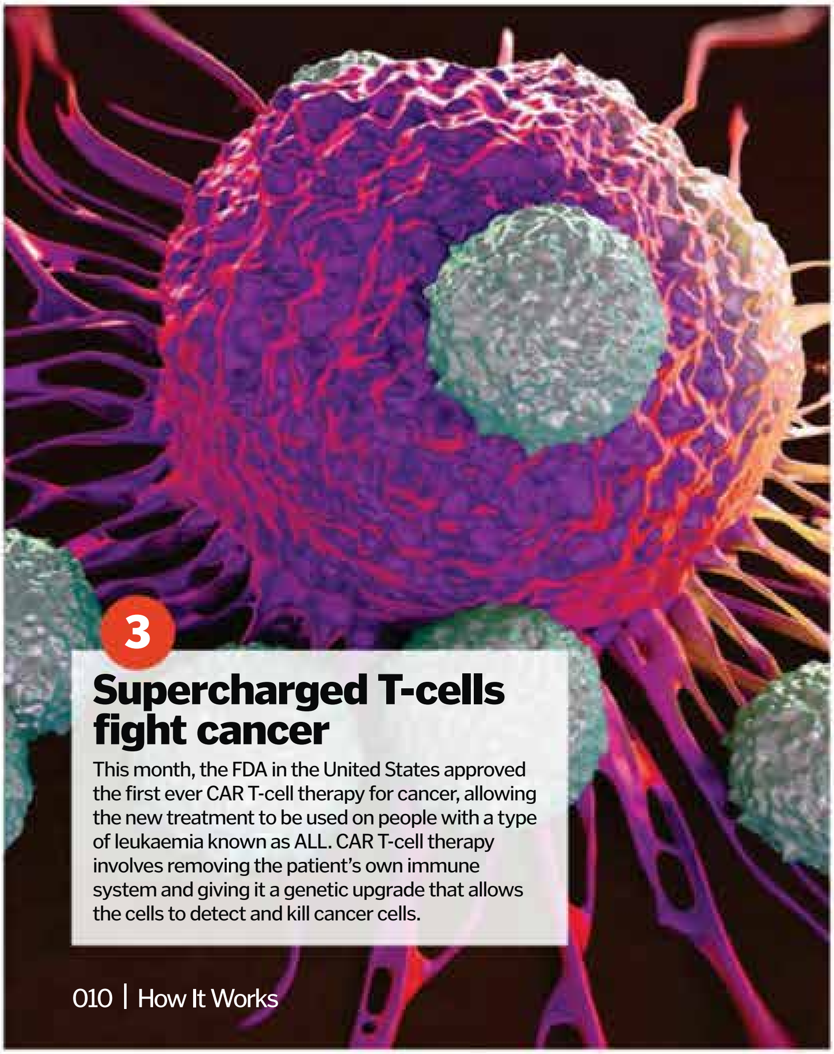
1 The solar eclipse was seen from space

The United States experienced a total solar eclipse in August as the Moon slid between the Sun and the Earth, casting a vast shadow over North America that was visible from outer space. And as day turned into night, NASA's spacecraft watched the country go dark from above, with the International Space Station, the Lunar Reconnaissance Orbiter, EPIC, and others snapping some impressive photographs of the event.



2 Scientists can trigger yawns with electricity

Researchers looking at the mechanism behind contagious yawning have monitored people's brains to pinpoint the part of the brain responsible. By exciting the area using electrical stimulation, they managed to increase the chance of their participants catching a yawn. Scientists are hoping to use the research to understand more about conditions like Tourette's syndrome, epilepsy and dementia.



3 Supercharged T-cells fight cancer

This month, the FDA in the United States approved the first ever CAR T-cell therapy for cancer, allowing the new treatment to be used on people with a type of leukaemia known as ALL. CAR T-cell therapy involves removing the patient's own immune system and giving it a genetic upgrade that allows the cells to detect and kill cancer cells.

4 Neanderthals made tar

Neanderthals might not have been able to build their own fires, but new research suggests that they could have rolled birch bark into small parcels and covered them in ashes from wildfires to create tar. This sticky substance has been found in parts of Europe inhabited by Neanderthals before humans arrived. It allowed the ancient apes to create advanced tools by gluing one material to another.

5 Dogs are self aware

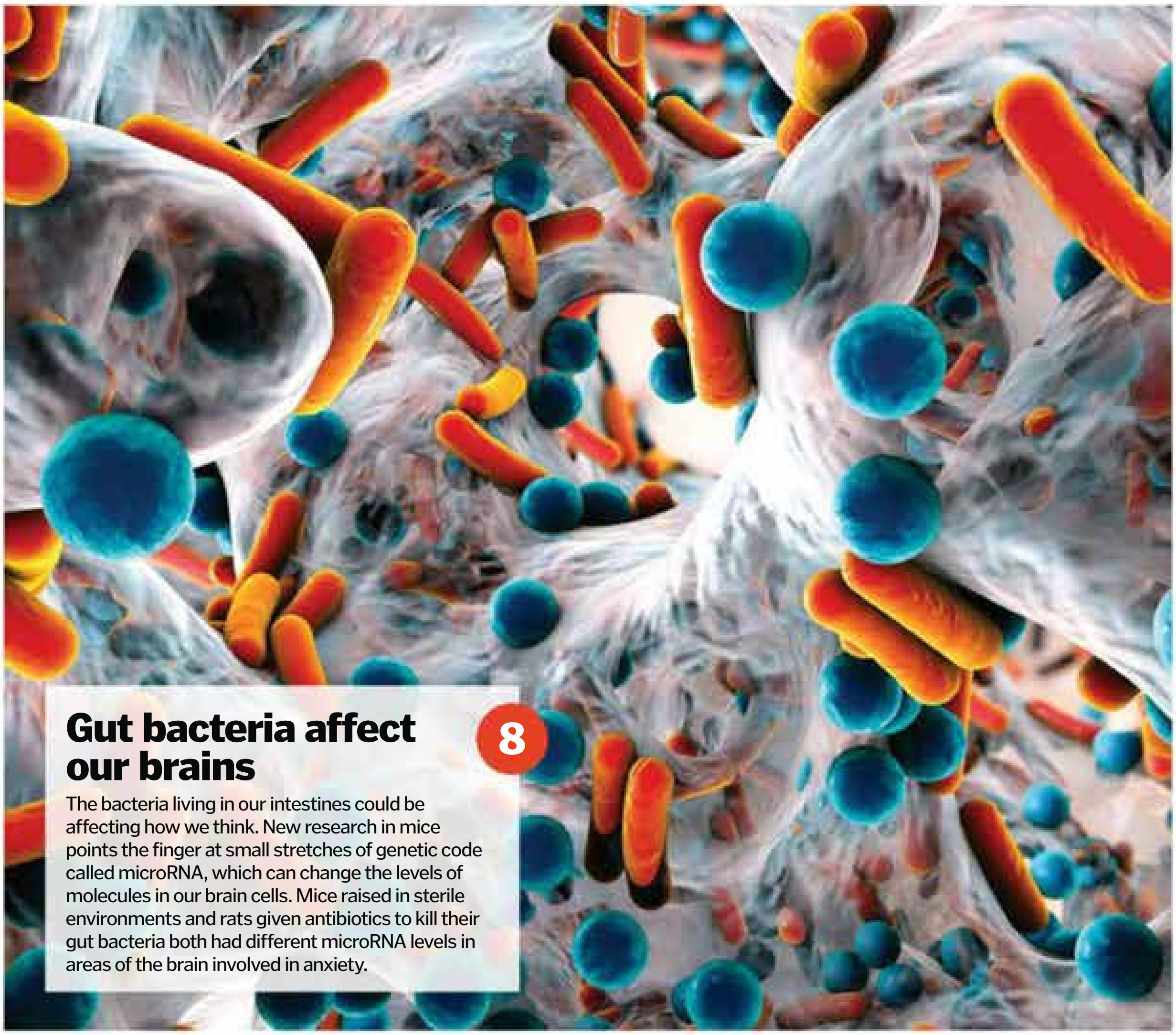
The normal test for self-awareness asks whether an animal notices the change in their reflection if a dot is placed on their face. Only the smartest animals do, and our favourite pets rely on their noses more than their eyes. However, while new tests have revealed that they might not notice themselves in a mirror, dogs can recognise their own unique scent.

6 People can echolocate with clicks

A computer science team has been examining adults who have learnt to echolocate by clicking and listening for subtle echoes. On average, the sounds last for three milliseconds, reach up to ten Hz and come out of their mouths in a 60 degree cone.

7 Antarctic life is at risk

Computer models have predicted that almost 80 per cent of local invertebrate life will suffer as Antarctic waters warm up. They live at the bottom of the coldest ocean in the world, and if it heats up they've got nowhere to go.

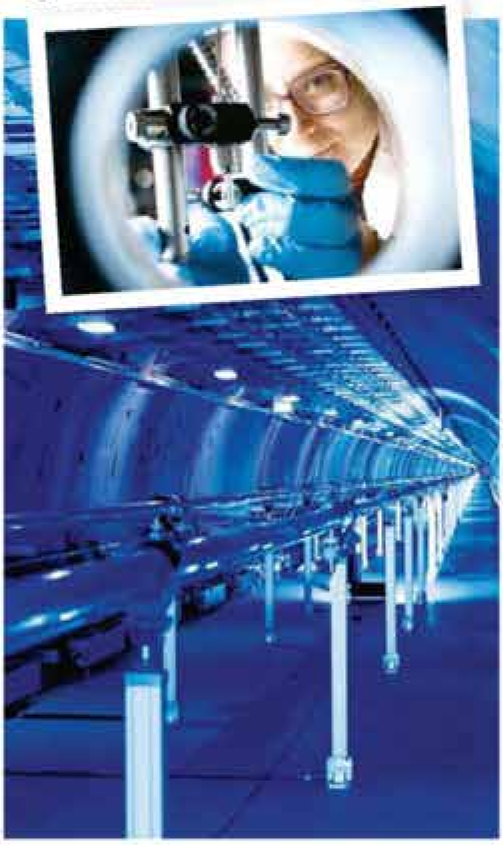


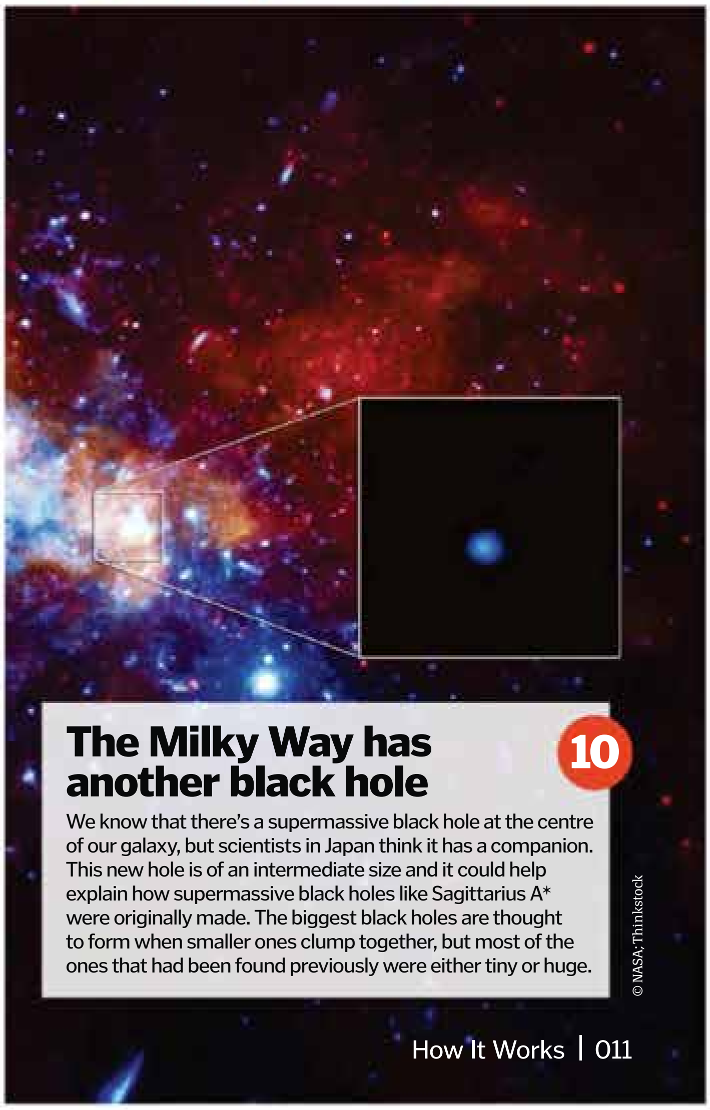
Gut bacteria affect our brains 8

The bacteria living in our intestines could be affecting how we think. New research in mice points the finger at small stretches of genetic code called microRNA, which can change the levels of molecules in our brain cells. Mice raised in sterile environments and rats given antibiotics to kill their gut bacteria both had different microRNA levels in areas of the brain involved in anxiety.

9 Europe's got an X-ray laser

The European X-ray Free Electron Laser (XFEL) in Hamburg, Germany, was switched on at the start of September in preparation to bombard samples with bright light to understand their structure at an atomic level. It features 3.4 kilometres of underground tunnels and its X-ray flashes will be used to collect around 3,000 images a second.





The Milky Way has another black hole 10

We know that there's a supermassive black hole at the centre of our galaxy, but scientists in Japan think it has a companion. This new hole is of an intermediate size and it could help explain how supermassive black holes like Sagittarius A* were originally made. The biggest black holes are thought to form when smaller ones clump together, but most of the ones that had been found previously were either tiny or huge.

© NASA; Thinkstock

FLY TO THE FUTURE

Teased by science fiction for decades, flying cars may finally be getting off the ground

DID YOU KNOW? Eddie Rickenbacker wrote the first story about flying cars in July 1924

When *The Jetsons* debuted on television in 1962, astronaut John Glen had just become the first American to orbit Earth. But during the optimism of the early space age, when rockets, satellites and nuclear power were on everyone's mind, it must have seemed like we would all be flying to work in a hover car like George Jetson within a few years. Yet despite ever more lifelike flying cars on screen — from Luke's landspeeder in *Star Wars* to those in the recent *Total Recall* remake — we're still waiting for them to make the leap from science fiction to science fact. However, that wait may soon be over.

This year has seen a flying car frenzy. At least two working prototypes have been unveiled, with the Lilium Jet going on its maiden voyage in Munich and the Kitty Hawk Flyer publicly demonstrated in San Francisco Bay. Meanwhile, ride-hailing app Uber has announced plans to launch a network of airborne taxis in Dubai and Texas, and Slovakian company Aeromobil is now reserving its fleet of 500 flying super cars to buy.

Google co-founder Larry Page has not only invested in Kitty Hawk this year but has also been funding another flying car company called Zee.Aero since 2010. Beyond the startup scene, both aerospace and auto industry giants, including Toyota and Airbus, have also committed to developing honest-to-goodness flying cars.

So why now? The last few years have seen some major technological breakthroughs that could help flying cars finally lift off. Many of the designs we're seeing now use electric propulsion rather than jet fuel. This is because battery technology has witnessed vast improvements in recent years driven by the demand for hybrid and electric cars.

While some concept vehicles still imagine humans in control behind the wheel, advances in so-called 'machine learning', which is essentially artificial intelligence, have led many companies to pursue self-driving flying cars. This means the user won't be required to own a

For years little more than a fanciful sketch, flying cars are rapidly becoming a reality

EVOLUTION OF FLYING CARS

1917

Resembling a Model T with detachable triplane wings, the Curtiss Autoplane only achieved a few short hops and was grounded indefinitely once the US entered the First World War.

1921

The Tampier Roadable was a biplane with four wheels, removable wings and and a land speed of 24 kilometres per hour. Its inventor Rene Tampier flew it to the Paris Air Salon then drove down the Champs-Élysées.

1946

The Airphibian was the first flying car to be certified as safe to fly by the US government and famed pilot Charles Lindbergh also endorsed it. But escalating development costs meant the inventor was forced to abandon it.

1957

The US Army developed the Piasecki VZ-8, a hybrid jeep-helicopter that could fly low enough to evade radar. It had two large horizontal propellers that allowed it to take off vertically and fly at 136 kilometres per hour.

1965

The Wagner Aerocar's bubble cockpit and tailfins make it look more like a helicopter with wheels than something out of *The Jetsons*. Its development was suspended in 1971.

1990s

The Moller M400 Skycar caused quite a buzz in the 90s with its sleek, rocket-like design. Sadly, Moller has since abandoned the project and is auctioning off the prototype through eBay.

1980s

Looking like something out of the kitsch 1970s version of *Battlestar Galactica* (in a good way), Boeing built three prototypes for its Sky Commuter, but the project was ultimately scrapped.

2017

Lilium completed a successful test flight of the world's first all-electric vertical take off and landing jet this year. The tested prototype was a two-seater, but the finished jet will carry five passengers.

> "AeroMobil is now reserving its fleet of 500 flying super cars to buy"

© WIKI; Ehang; Boeing; Lilium; Moller

The Aeromobil's chassis is made almost entirely out of ultra lightweight carbon fibre

pilot's licence, which is expensive and time-consuming to get, making flying cars more accessible for everyone.

The popularity of consumer drones, while much smaller and lighter, have also helped to drive down the cost of some components. In fact, the industries overlap; Chinese drone maker EHang are developing a self-flying taxi that looks like an oversized quadrocopter.

However, having been cruelly let down by pie in the sky fantasies about flying cars in the past, it's important that we stay grounded. Most of the manufacturers that have made announcements this year also say we won't actually be whizzing through the skies until 2020 or 2025. While the tech that underpins these vehicles is pretty much there, it will take years to fully develop them, carry out the necessary test flights and safety checks, as well as make the whole process simple enough that these flying cars could be affordably mass-produced.

Despite spurring on many of the innovations that make flying cars possible, Tesla CEO Elon Musk has reservations about flying cars. "Obviously, I like flying things," he told *Bloomberg*, referring to his other side line, private rocket company Space X. "But it's difficult to imagine the flying car becoming a scaleable solution." He also has concerns about mid-air fender benders. "If somebody doesn't maintain their flying car, it could drop a hubcap and guillotine you," Musk said. "Your anxiety level will not decrease as a result of things that weigh a lot buzzing around your head."

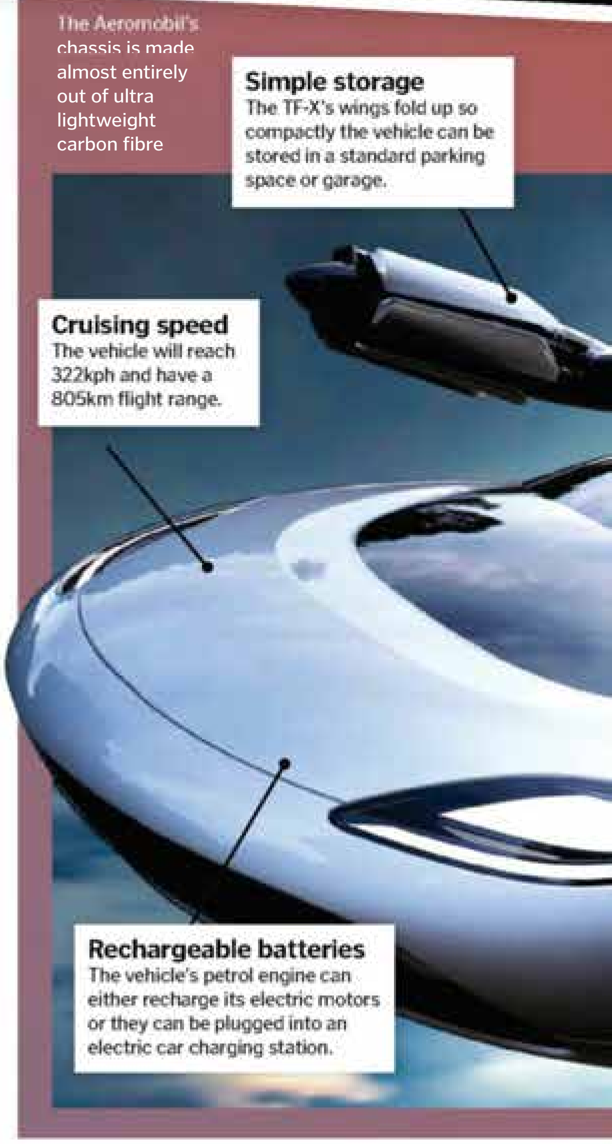
It's easy to dismiss Musk's skepticism due to the fact he is developing an entirely different form of transport that would see drivers travel in high-speed underground tunnels or 'hyperloops' rather than fly. However, many aerospace engineers and aviation experts have expressed similar concerns about the danger of the sky filling up with commuter traffic as airports, urban helipads and air traffic control would come under unprecedented pressure.

As part of their plans to create a fleet of flying taxis, Uber have committed to building so-called 'vertiports'. On the one hand these are intended to ensure that landing pads are as accessible to users as their conventional, earthbound taxis. However, they will also go a long way to easing demand on existing infrastructure. Uber says it is scouting locations for sites already. However, it remains to be seen how this will work with local zoning regulations, not to mention residents.

Chinese firm EHang plan to build private air traffic control towers wherever their passenger drones operate. One of these 'command centres' is already up and running in Guangzhou, where EHang carry out their test flights. These centres will monitor the autonomous shuttles, receiving live feed readings, including speed, altitude, individual propeller power, and location. The staff will also be able to view camera feeds from the drone and communicate directly with the passengers inside.

These are only the first steps towards making our skies safe for airborne commuters; government agencies in every country will likely impose their own rules and restrictions. However, if rules for the sky can be established, flying cars have the power to transform not just the way we travel but how we live our lives. For example, if you can fly long distances in half the time you can drive them, why live in expensive, cramped cities at all?

Alternatively, if we all get used to living the high life, jetting from location to location, is there even any reason to return to street level? Read on to discover how flying cars have evolved, the tech that makes them tick and what the future may look like when they finally fulfil our Jetson dreams.

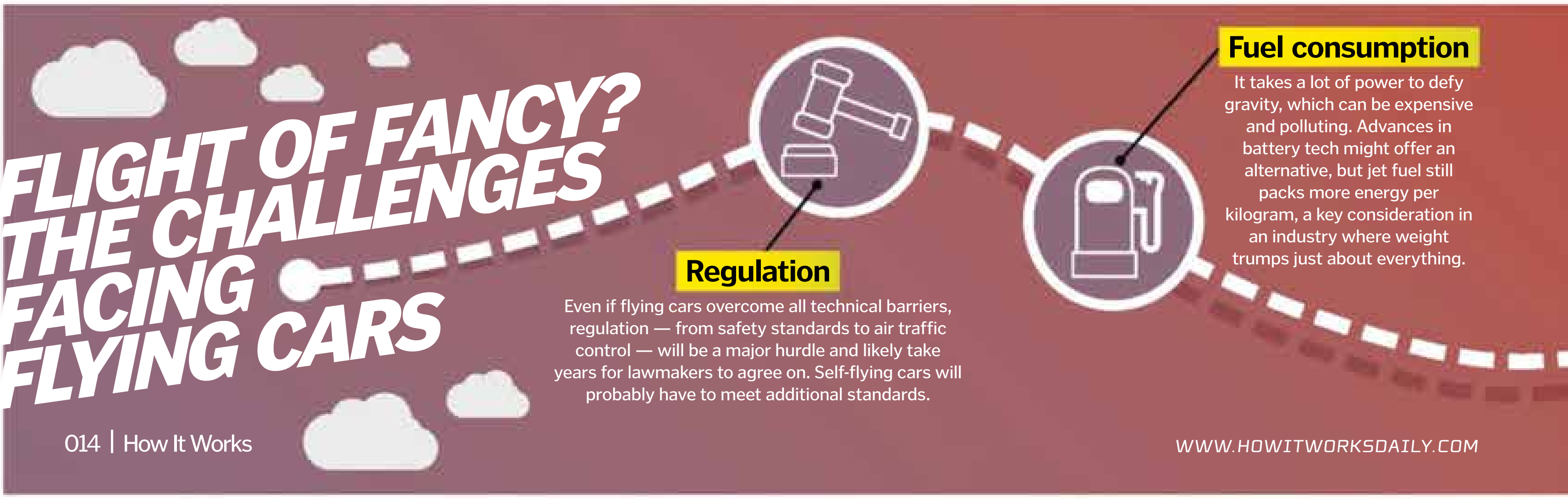


Simple storage
The TF-X's wings fold up so compactly the vehicle can be stored in a standard parking space or garage.

Cruising speed
The vehicle will reach 322kph and have a 805km flight range.

Rechargeable batteries
The vehicle's petrol engine can either recharge its electric motors or they can be plugged into an electric car charging station.

FLIGHT OF FANCY? THE CHALLENGES FACING FLYING CARS

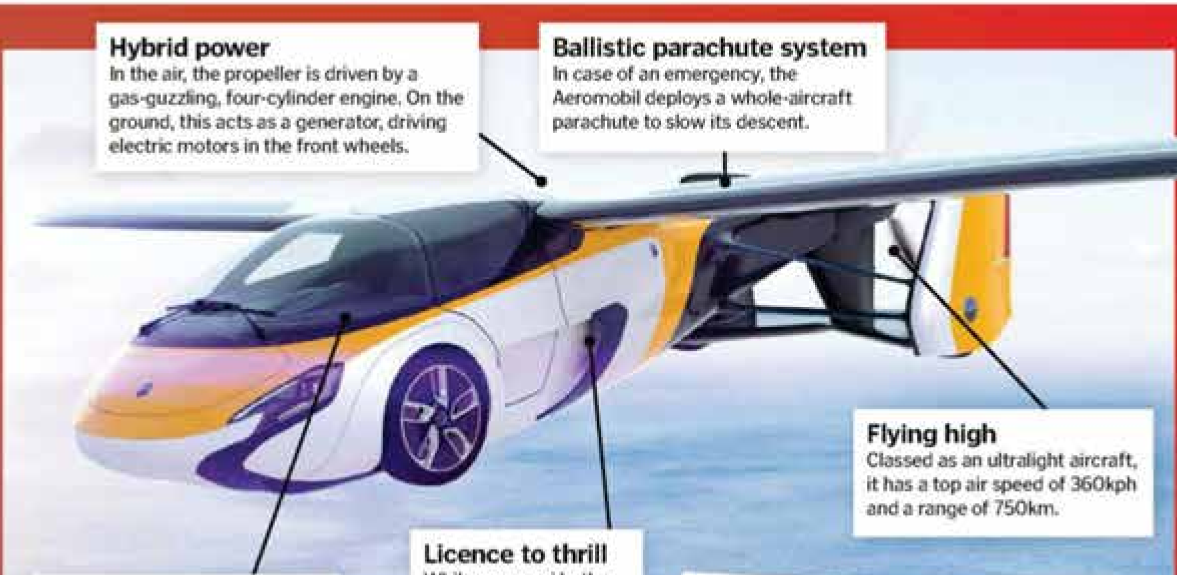


Fuel consumption
It takes a lot of power to defy gravity, which can be expensive and polluting. Advances in battery tech might offer an alternative, but jet fuel still packs more energy per kilogram, a key consideration in an industry where weight trumps just about everything.

Regulation
Even if flying cars overcome all technical barriers, regulation — from safety standards to air traffic control — will be a major hurdle and likely take years for lawmakers to agree on. Self-flying cars will probably have to meet additional standards.

The flying car in disguise

The Aeromobil is a real-life Transformer. To see it in driving mode you could mistake the slick carbon fibre Aeromobil for some kind of experimental supercar. But in just three minutes this sporty two-seater can be ready for take off as wings unfurl from its roof and a rear propeller pops out at the back. Then all you need is an airfield or a long stretch of empty road and you're cruising at 10,000 feet. Unfortunately, the Aeromobil is also being sold like a supercar — only 500 are being made and each one will cost $1.2 million (£908,400).



Hybrid power
In the air, the propeller is driven by a gas-guzzling, four-cylinder engine. On the ground, this acts as a generator, driving electric motors in the front wheels.

Ballistic parachute system
In case of an emergency, the Aeromobil deploys a whole-aircraft parachute to slow its descent.

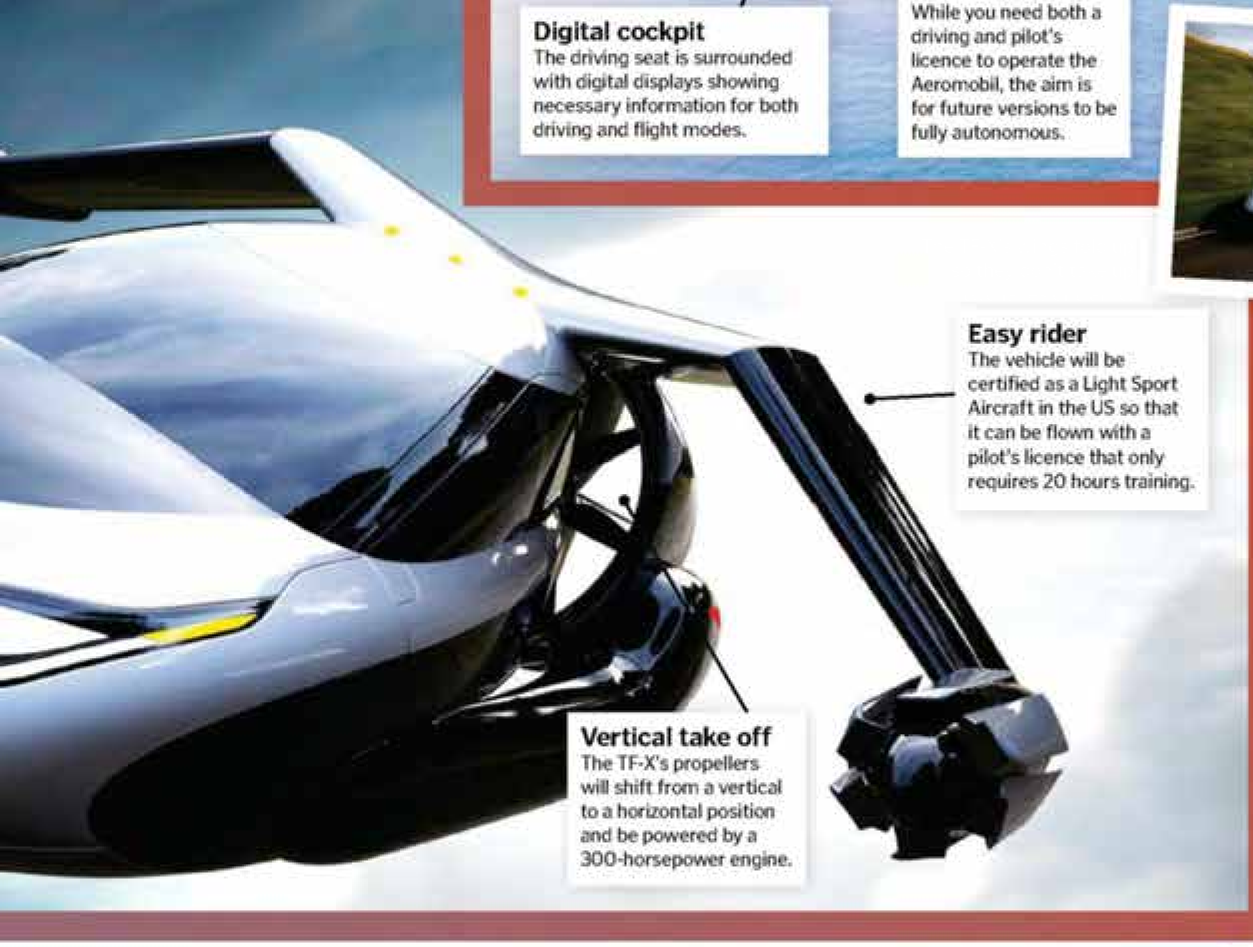
Flying high
Classed as an ultralight aircraft, it has a top air speed of 360kph and a range of 750km.

Digital cockpit
The driving seat is surrounded with digital displays showing necessary information for both driving and flight modes.

Licence to thrill
While you need both a driving and pilot's licence to operate the Aeromobil, the aim is for future versions to be fully autonomous.

The TF-X is (almost) ready for vertical take off

Terrafugia (Latin for 'escape the Earth') has been developing flying cars since 2006. Its most exciting concept, the TF-X, looks like a four-seater SUV with fold-up wings. But its most exciting feature is that its propellers can shift position so that the TF-X can vertically take off and land (VTOL) like a helicopter — meaning it doesn't require a long runaway — before switching to conventional horizontal flight. Terrafugia has been teasing flying car tech for years now, but its recent purchase of Volvo's parent company Geely might get the TF-X off the ground.



Easy rider
The vehicle will be certified as a Light Sport Aircraft in the US so that it can be flown with a pilot's licence that only requires 20 hours training.

Vertical take off
The TF-X's propellers will shift from a vertical to a horizontal position and be powered by a 300-horsepower engine.

> "Many engineers have expressed concerns about the sky filling with traffic"

Noise pollution
As anyone who has heard a helicopter land or flown a drone will know, VTOL vehicles, which generate a lot of downward force, make a lot of noise for people on the ground. This will not endear flying cars to the public.

Qualified pilots
Even if the controls can be simplified (perhaps with the aid of AI), flying a vehicle requires a different set of skills to driving. Alternatively, hiring a pilot to fly you can cost £500 ($660) an hour.

Infrastructure
Most major cities boast a few helipads, but these are not designed to handle heavy commuter traffic. Uber plans to build its own urban vertiports to ease the burden, but these will have to meet strict regulations and will possibly face opposition from local residents.

© Getty; Aeromobil

SKY RIDE

These airborne options plan to offer customers low-cost, short-distance rides

A realistic flying machine

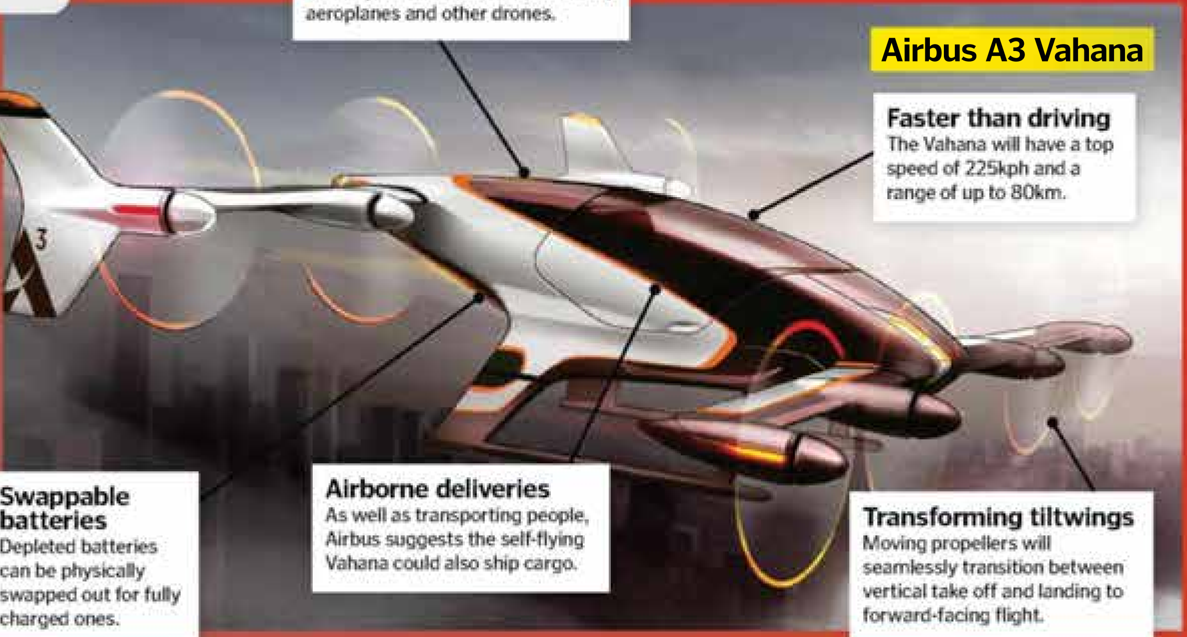
While there are lots of startups promising they will invent the flying car first, Airbus is approaching the challenge with nearly 50 years experience building real-life planes. While it looks like something out of science fiction, the Airbus A3 Vahana (pronounced 'A-cubed') is designed around existing wing and landing gear technology. A full-sized prototype is already in the works, with demonstrations promised before the end of 2017.

The Lilium Jet doesn't actually use jet fuel

In April, the Lilium Jet made its maiden voyage at a Munich airfield, proving that this all-electric aircraft can take to the sky. However, its flight only lasted a few minutes, with no one in either of its two seats and a pilot controlling it from the ground. Backed by the European Space Agency, Lilium is confident it can develop the battery power needed to offer an on-demand taxi service by 2025.

The self-piloting drone that you can ride inside

The 1.4-metre-high EHang 184 can fly passengers distances of up to 16 kilometres at around 100 kilometres per hour. The 184 flies itself, so all you have to do is punch your destination into a smartphone app that connects with the 184 via the vehicle's built-in Wi-Fi and off you go. Though a summer trial had to be rescheduled, EHang are expected to buzz passengers around Dubai soon.



Airbus A3 Vahana

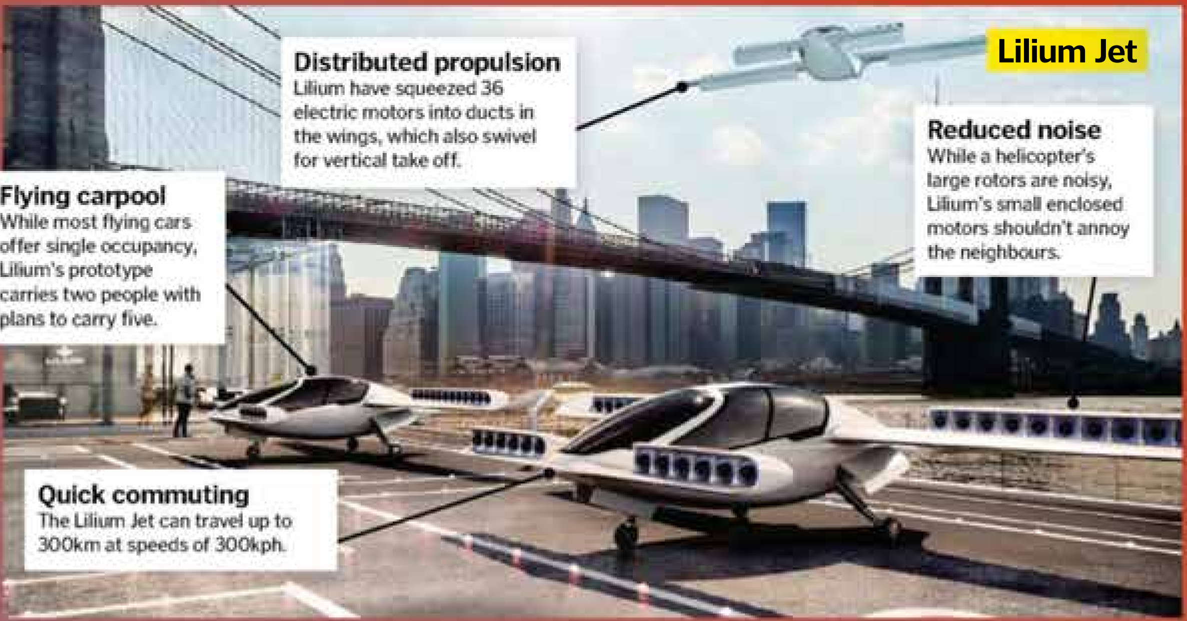
Smart sensors
Cameras, radar and lidar sensors will help it manoeuvre around birds, aeroplanes and other drones.

Faster than driving
The Vahana will have a top speed of 225kph and a range of up to 80km.

Swappable batteries
Depleted batteries can be physically swapped out for fully charged ones.

Airborne deliveries
As well as transporting people, Airbus suggests the self-flying Vahana could also ship cargo.

Transforming tiltwings
Moving propellers will seamlessly transition between vertical take off and landing to forward-facing flight.



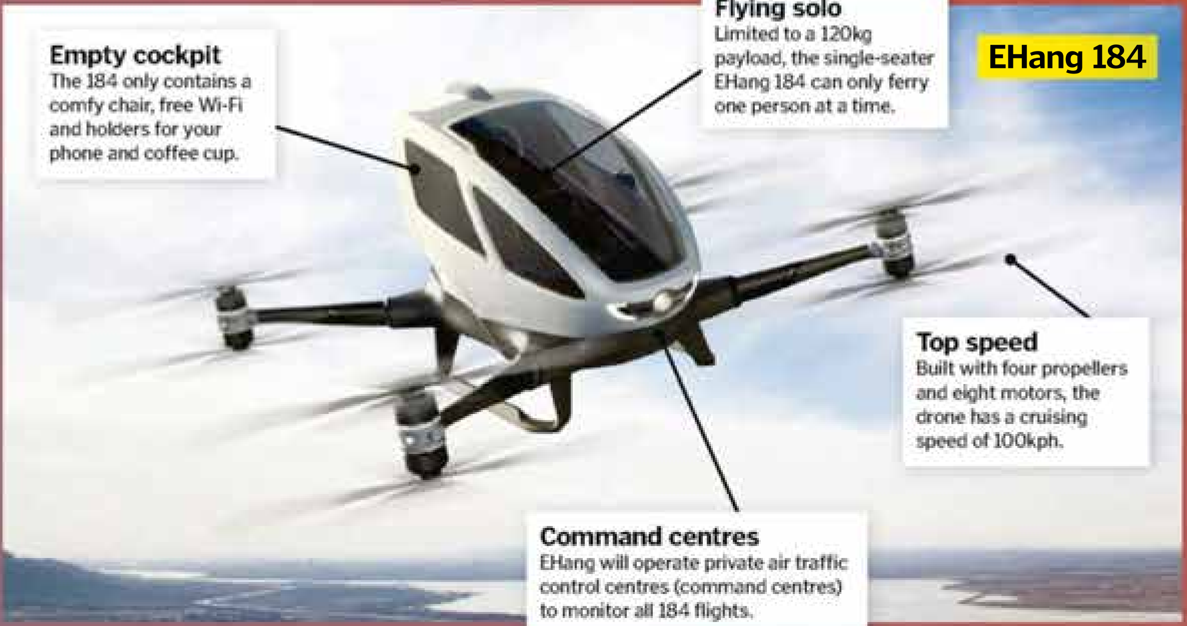
Lilium Jet

Distributed propulsion
Lilium have squeezed 36 electric motors into ducts in the wings, which also swivel for vertical take off.

Reduced noise
While a helicopter's large rotors are noisy, Lilium's small enclosed motors shouldn't annoy the neighbours.

Flying carpool
While most flying cars offer single occupancy, Lilium's prototype carries two people with plans to carry five.

Quick commuting
The Lilium Jet can travel up to 300km at speeds of 300kph.



EHang 184

Empty cockpit
The 184 only contains a comfy chair, free Wi-Fi and holders for your phone and coffee cup.

Flying solo
Limited to a 120kg payload, the single-seater EHang 184 can only ferry one person at a time.

Top speed
Built with four propellers and eight motors, the drone has a cruising speed of 100kph.

Command centres
EHang will operate private air traffic control centres (command centres) to monitor all 184 flights.

DID YOU KNOW? *While privately owning a flying car will be pricey, Airbus estimate a taxi ride will only cost $1.50 to $2.50 per mile*

Up, up and Uber!

Ride-hailing service Uber has announced it is also taking to the skies. The company will trial UberAIR flying taxis in Dubai and Dallas in 2020, which passengers will be able to summon using its regular mobile app.

"Urban aviation is a natural next step for Uber in this pursuit, which is why we are working to make 'push a button, get a flight' a reality," said Uber's chief product officer Jeff Holden at a press event. Holden added that while these flights will initially involve manned aircraft, they will eventually be cheaper, faster and more environmentally friendly than conventional Uber rides as they will use autonomous electric aircraft.

Uber has hired Mark Moore, a NASA aircraft engineer renowned for his VTOL work, and partnered with several aeronautic manufacturers to develop these vehicles. Once operational, Uber also plans to build vertiports — landing pads with charging ports — in easily accessible urban areas.

UberAIR will operate a network of aircraft flying distances of up to 40 kilometres

Uber is already scouting for locations to set up so-called vertiports

Kitty Hawk set to make a splash

Less of a flying car and more of a hovering jet ski, the Kitty Hawk Flyer is a single-person ultralight aircraft powered by eight electric rotors. Backed by Google co-founder Larry Page, the Flyer travels up to 40 kilometres an hour and lifts up to 4.5 metres into the air. Like the jet ski, the Flyer is recreational rather than a main mode of transport, designed strictly for use over water. However, Kitty Hawk insist that it doesn't require a pilot's licence to fly and you can master the controls within hours. A price has yet to be confirmed, but Kitty Hawk plan to start selling the Flyer (with more aesthetically pleasing bodywork) by the end of the year.

Kitty Hawk are not currently planning to ship the Flyer outside of the US

© Lilium; Airbus; E-Hang; Kitty Hawk, Photographer: Ian Martin; Uber; Getty/Warner Bros/ Handout; Alamy

TOP 5 FICTIONAL FLYING CARS

Chitty Chitty Bang Bang, *Chitty Chitty Bang Bang* (1968)

Created by eccentric inventor Caractacus Potts, the family-sized Chitty Chitty Bang Bang can fly the length of Europe and has a floatation device for evading pirates on water.

Scaramanga's AMC Matador, *The Man With The Golden Gun* (1974)

Bond villain Scaramanga used a Coupé that transformed into a plane for a daring kidnap. 007 mentions it flying "200 miles west of Bangkok".

Police Spinner, *Blade Runner* (1982)

Ideal for patrolling the skyscrapers that loom over futuristic LA, the police cars in Ridley Scott's sci-fi detective story take off vertically and hover in the air like a Harrier Jump Jet.

DeLorean DMC-12, *Back To The Future Part II* (1989)

As if turning it into a time machine in the first film wasn't enough, Doc Brown upgrades his car for the sequel with technology from 2015, where all cars — and skateboards — fly.

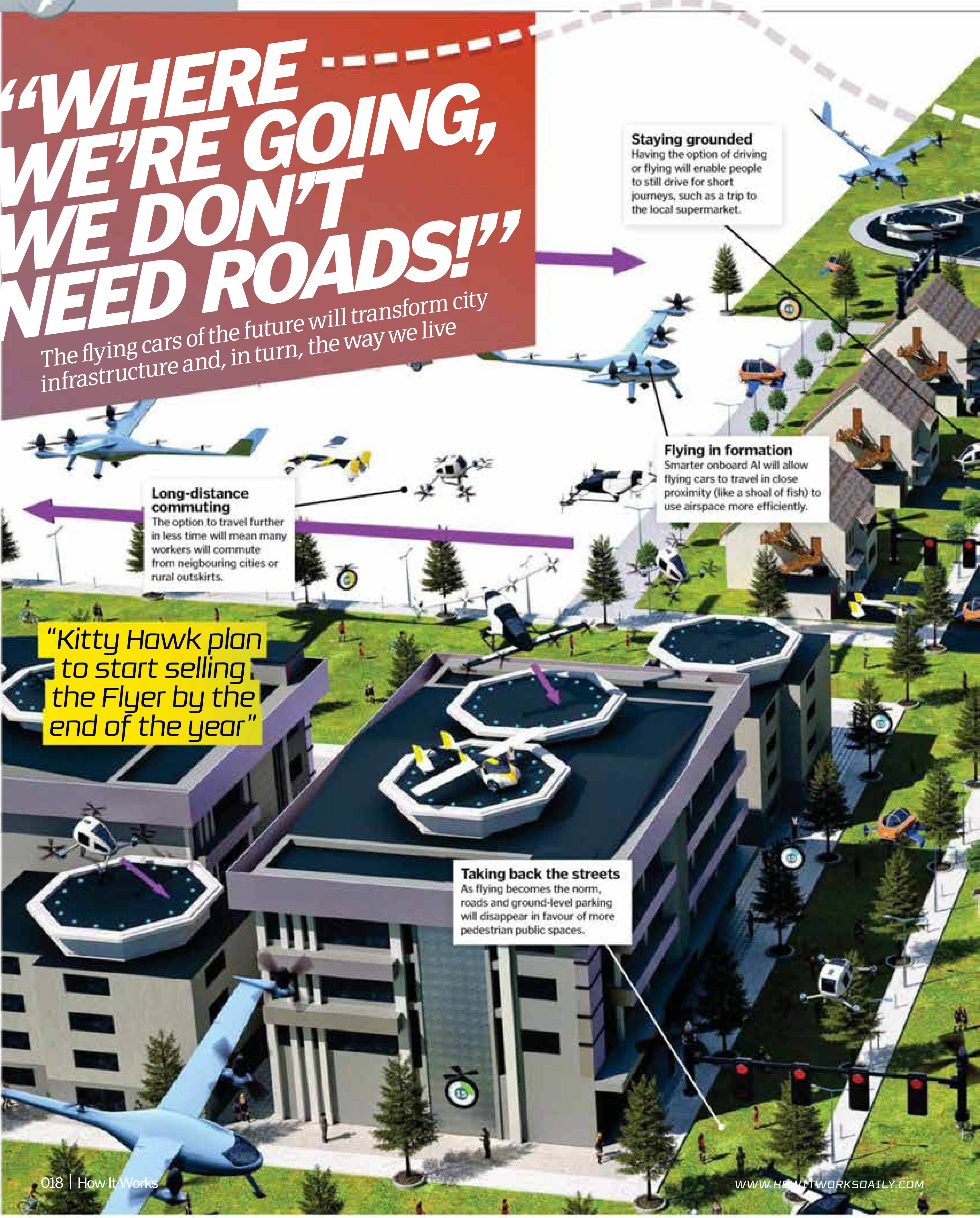
Skyjet, *Valerian and the City of a Thousand Planets* (2017)

The Skyjet in Luc Besson's sci-fi epic can switch between urban and interstellar travel and was designed by real-life manufacturer Lexus.

> "Uber is set to trial flying taxis in Dubai and Dallas in 2020"

"WHERE WE'RE GOING, WE DON'T NEED ROADS!"

The flying cars of the future will transform city infrastructure and, in turn, the way we live



Staying grounded
Having the option of driving or flying will enable people to still drive for short journeys, such as a trip to the local supermarket.

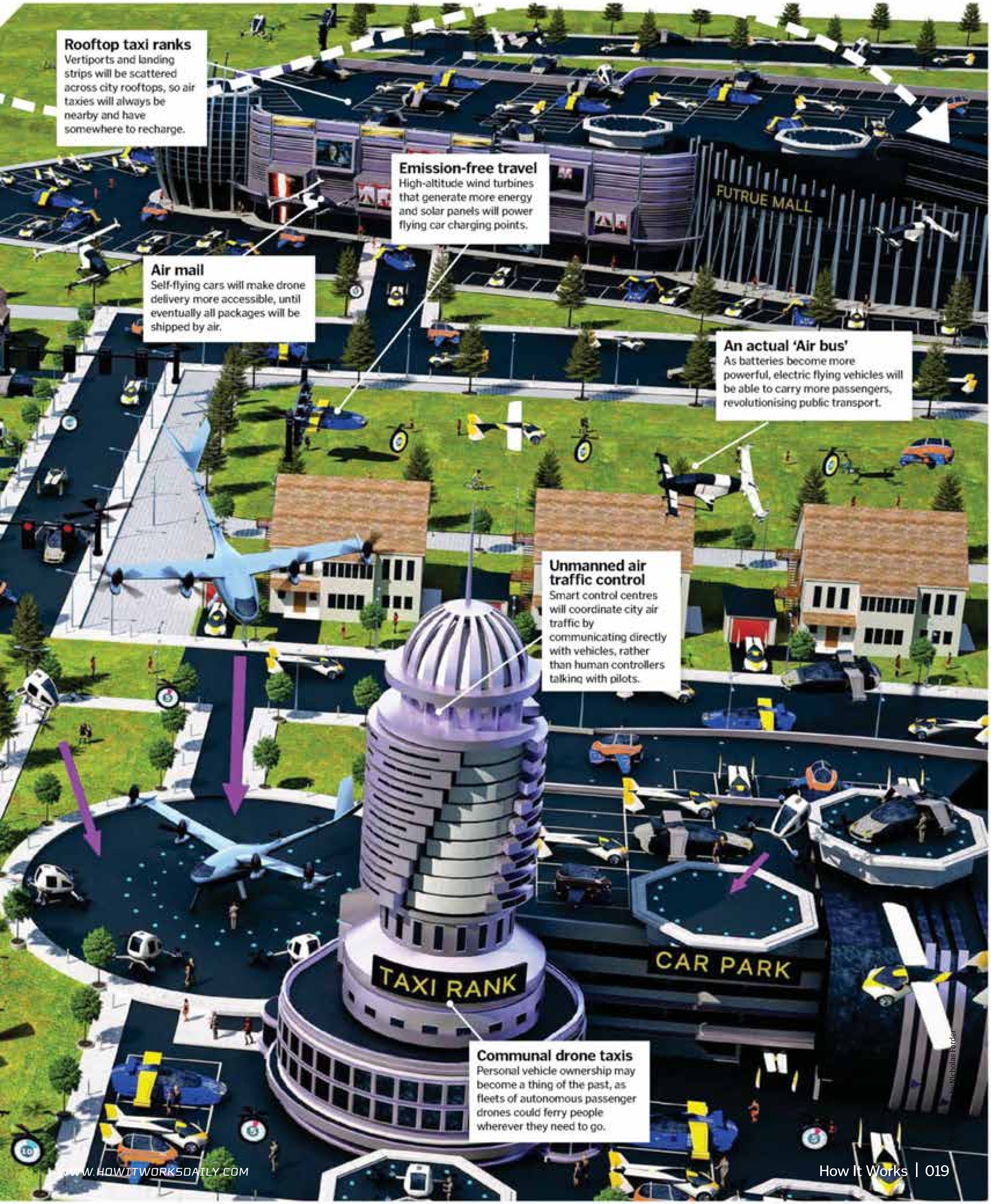
Flying in formation
Smarter onboard AI will allow flying cars to travel in close proximity (like a shoal of fish) to use airspace more efficiently.

Long-distance commuting
The option to travel further in less time will mean many workers will commute from neigbouring cities or rural outskirts.

> "Kitty Hawk plan to start selling the Flyer by the end of the year"

Taking back the streets
As flying becomes the norm, roads and ground-level parking will disappear in favour of more pedestrian public spaces.

DID YOU KNOW? *A robot arm made by Tesla can swap out rechargeable batteries in 90 seconds and could be used on flying cars*



Rooftop taxi ranks
Vertiports and landing strips will be scattered across city rooftops, so air taxies will always be nearby and have somewhere to recharge.

Emission-free travel
High-altitude wind turbines that generate more energy and solar panels will power flying car charging points.

Air mail
Self-flying cars will make drone delivery more accessible, until eventually all packages will be shipped by air.

An actual 'Air bus'
As batteries become more powerful, electric flying vehicles will be able to carry more passengers, revolutionising public transport.

Unmanned air traffic control
Smart control centres will coordinate city air traffic by communicating directly with vehicles, rather than human controllers talking with pilots.

Communal drone taxis
Personal vehicle ownership may become a thing of the past, as fleets of autonomous passenger drones could ferry people wherever they need to go.

© Illustration by Nicholas Forder

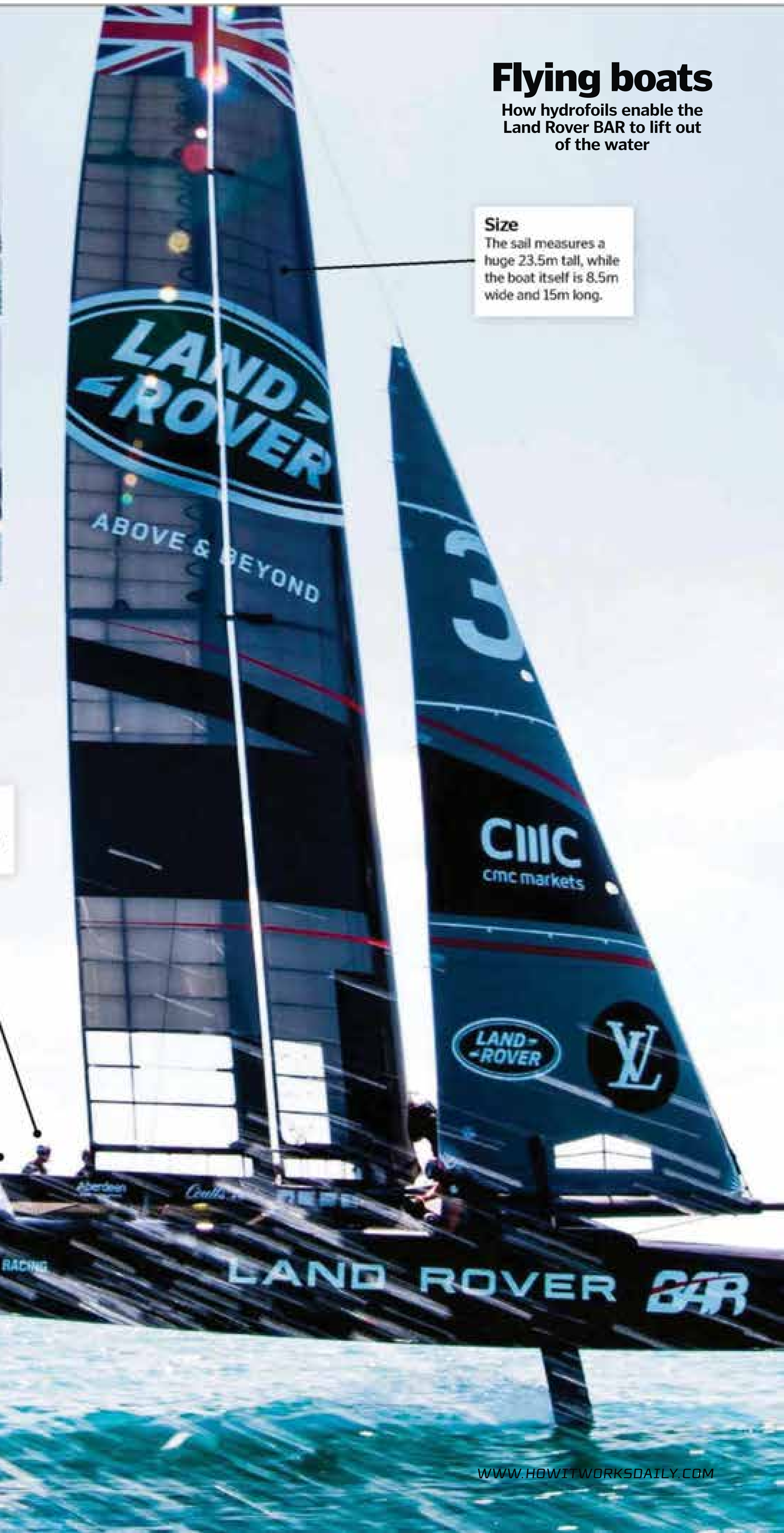
Flying boats

How hydrofoils enable the Land Rover BAR to lift out of the water

Is it a bird? Is it a plane? Nope, it's still a boat

A crew on a large hydrofoil boat need to work together to operate it

> "Hydrofoils allow boats to lift out of the water"



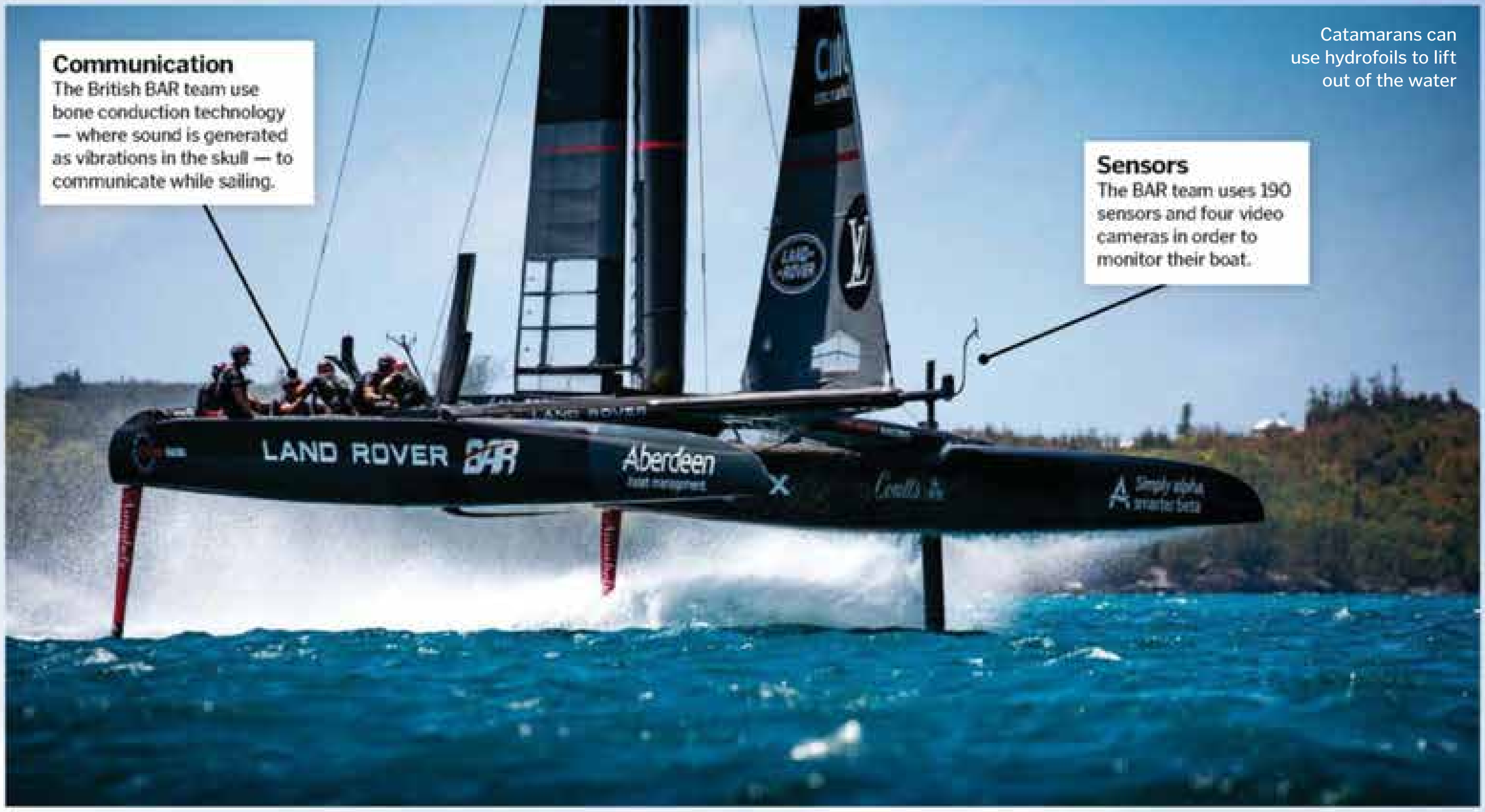
Size
The sail measures a huge 23.5m tall, while the boat itself is 8.5m wide and 15m long.

Power
A crew of six generates 1,200 watts of power to operate the boat.

Weight
The whole boat weighs about 2,400kg and took 35,000 hours to build.

Hydrofoils
Two hydrofoils, one under each side, allow the boat to generate lift as it speeds forward.

DID YOU KNOW? *The first hydrofoil was built in 1906 by Italian Enrico Forlanini, enabling him to reach speeds of 68kph*



Communication
The British BAR team use bone conduction technology — where sound is generated as vibrations in the skull — to communicate while sailing.

Sensors
The BAR team uses 190 sensors and four video cameras in order to monitor their boat.

Catamarans can use hydrofoils to lift out of the water

Hydrofoils

How this technology helps boats fly almost like a plane

Hydrofoils are a rather incredible piece of technology that enable boats to lift out of the water. This removes the contact between the water and the hull of the boat, allowing them to reach high speeds. The idea of a hydrofoil has been around for decades but only recently has it been more widely applied in activities like sailing.

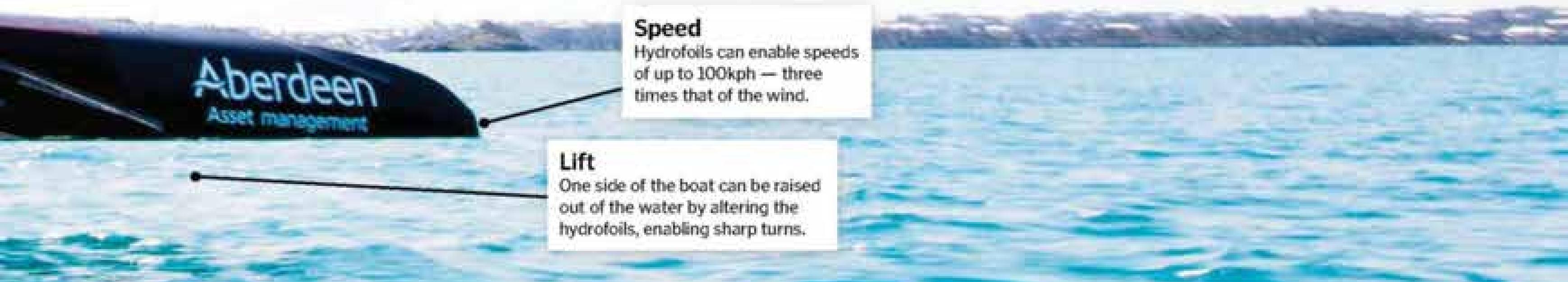
Traditional sailboats use a keel to keep them balanced in the water as the wind pushes against the sail. This is essentially a counterweight in the water. A hydrofoil replaces the keel with a wing-shaped structure, which pushes down under the water and generates lift as the boat moves forwards and water rushes over it. As water is much denser than air, the rate of lift is about 1,000 times greater than that of a plane wing.

At a high enough speed this will cause enough lift to raise the boat out of the water. Too much speed and the water under the boat will churn, causing it to stall and fall back into the water. Too little speed, however, and not enough lift will be generated. When used optimally, hydrofoils can enable a boat to go three-times faster than the wind speed. Often made from carbon fibre, hydrofoils must be raised, lowered and tilted in order to get the optimal amount of lift and speed.

The use of hydrofoils has progressed quite a bit over the last few years. They had fallen out of favour for more general use due to their complexity and cost. However, they have recently been used in sporting contests like the America's Cup, one of the world's most prestigious sailboat competitions.

Hydrofoils come in all shapes and sizes, including smaller boats like this

© BAE Systems / Land Rover BAR; Getty



Speed
Hydrofoils can enable speeds of up to 100kph — three times that of the wind.

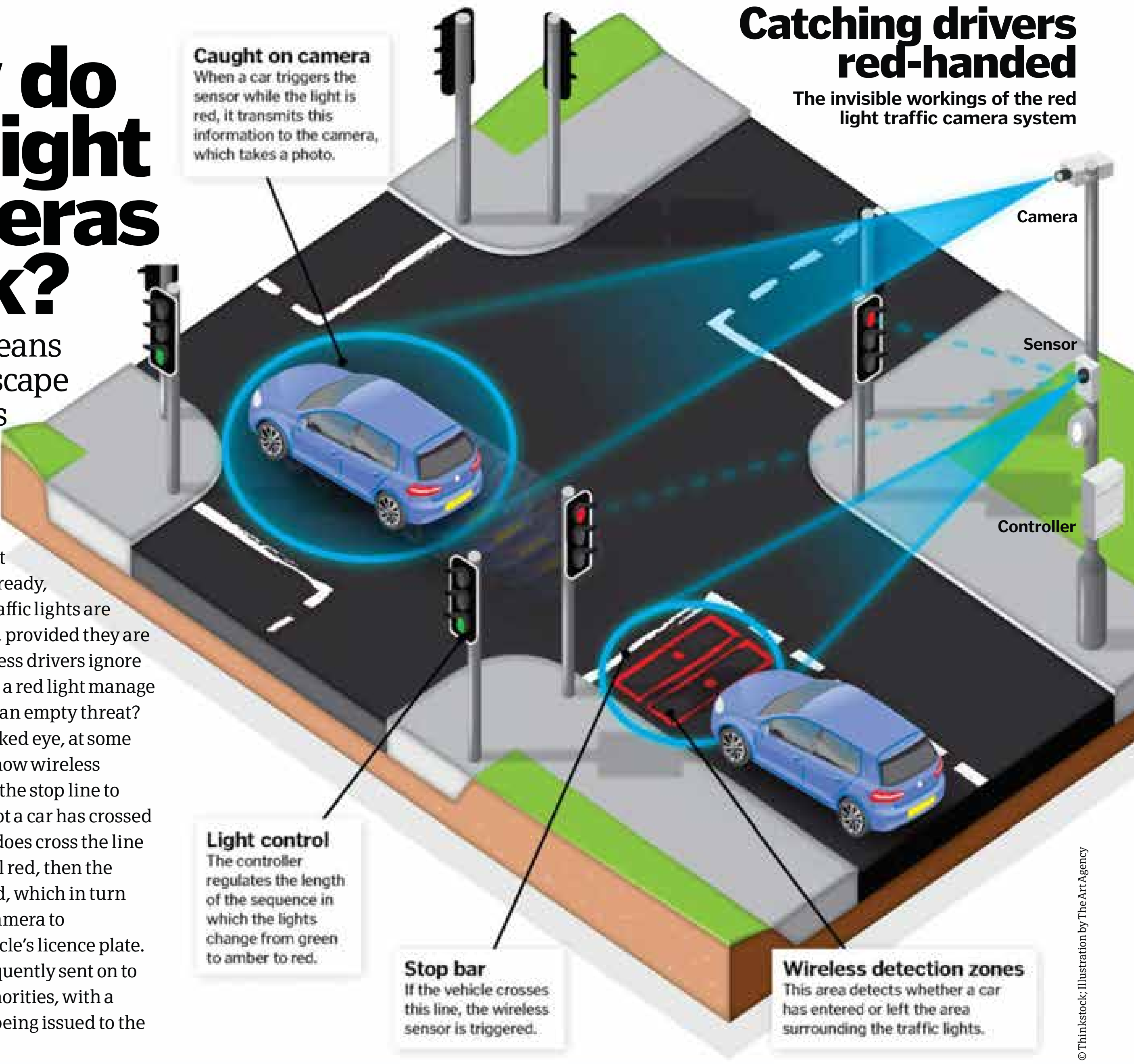
Lift
One side of the boat can be raised out of the water by altering the hydrofoils, enabling sharp turns.

How do red light cameras work?

New tech means there's no escape for motorists who ignore red lights

Red to stop, amber to start stopping/get ready, and green to go — traffic lights are simple and effective, provided they are obeyed. When reckless drivers ignore the signals, how can a red light manage to be more than just an empty threat?

Invisible to the naked eye, at some junctions there are now wireless detection sensors at the stop line to record whether or not a car has crossed the line. If a vehicle does cross the line while the light is still red, then the sensors are triggered, which in turn causes the nearby camera to photograph the vehicle's licence plate. This image is subsequently sent on to the appropriate authorities, with a penalty ticket then being issued to the vehicle's owner.



Catching drivers red-handed

The invisible workings of the red light traffic camera system

Caught on camera
When a car triggers the sensor while the light is red, it transmits this information to the camera, which takes a photo.

Light control
The controller regulates the length of the sequence in which the lights change from green to amber to red.

Stop bar
If the vehicle crosses this line, the wireless sensor is triggered.

Wireless detection zones
This area detects whether a car has entered or left the area surrounding the traffic lights.

© Thinkstock; Illustration by The Art Agency

There's a good reason why you can hear ambulances from such a long way off

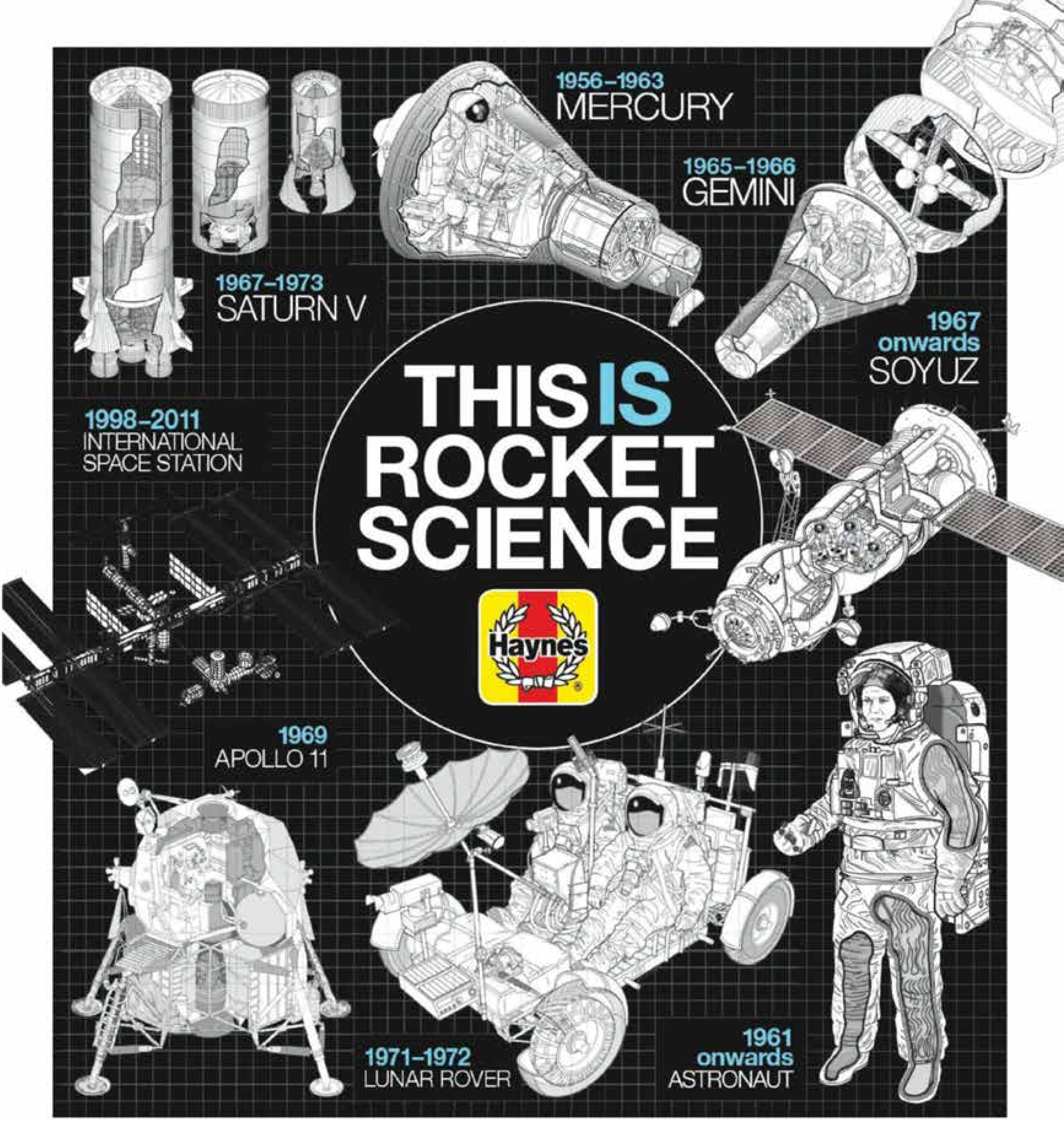
Pitching the perfect sirens

How emergency vehicles make themselves heard

Ambulances, fire trucks, police cars — we have become accustomed to hearing their approach thanks to the distinctive noise of their respective sirens. But how do they make that particular sound, and why do we respond to it in the way we do?

Much of the reason for the unique nature of the sound is the frequency range the sirens fall within: 1-3 kHz, which is where human hearing is most sensitive. Conversely, it is also the frequency at which our sound-location abilities are at their most ineffective — we're better at detecting the sources of sounds that are under 1kHz. Moreover, we can only know whether a sound is in front of or behind us if it is over 5kHz.

If the siren is too loud then it runs the risk of damaging the hearing of those in its immediate vicinity, meaning that many emergency vehicles compensate by having their sirens work at a higher pitch. Even then, relatively new developments, like soundproofing in cars, can have the effect of muffling sirens, meaning that manufacturers are having to devise new methods of innovation in this field.



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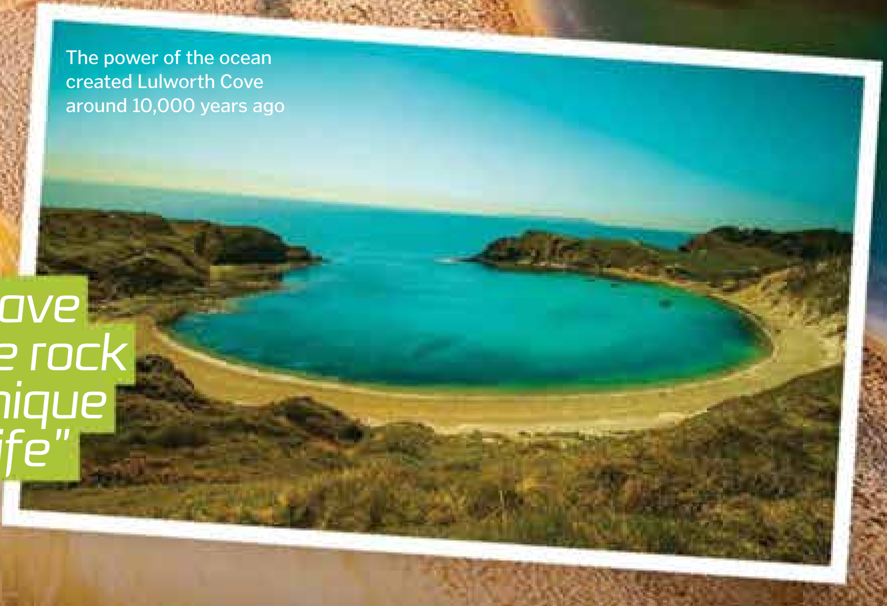


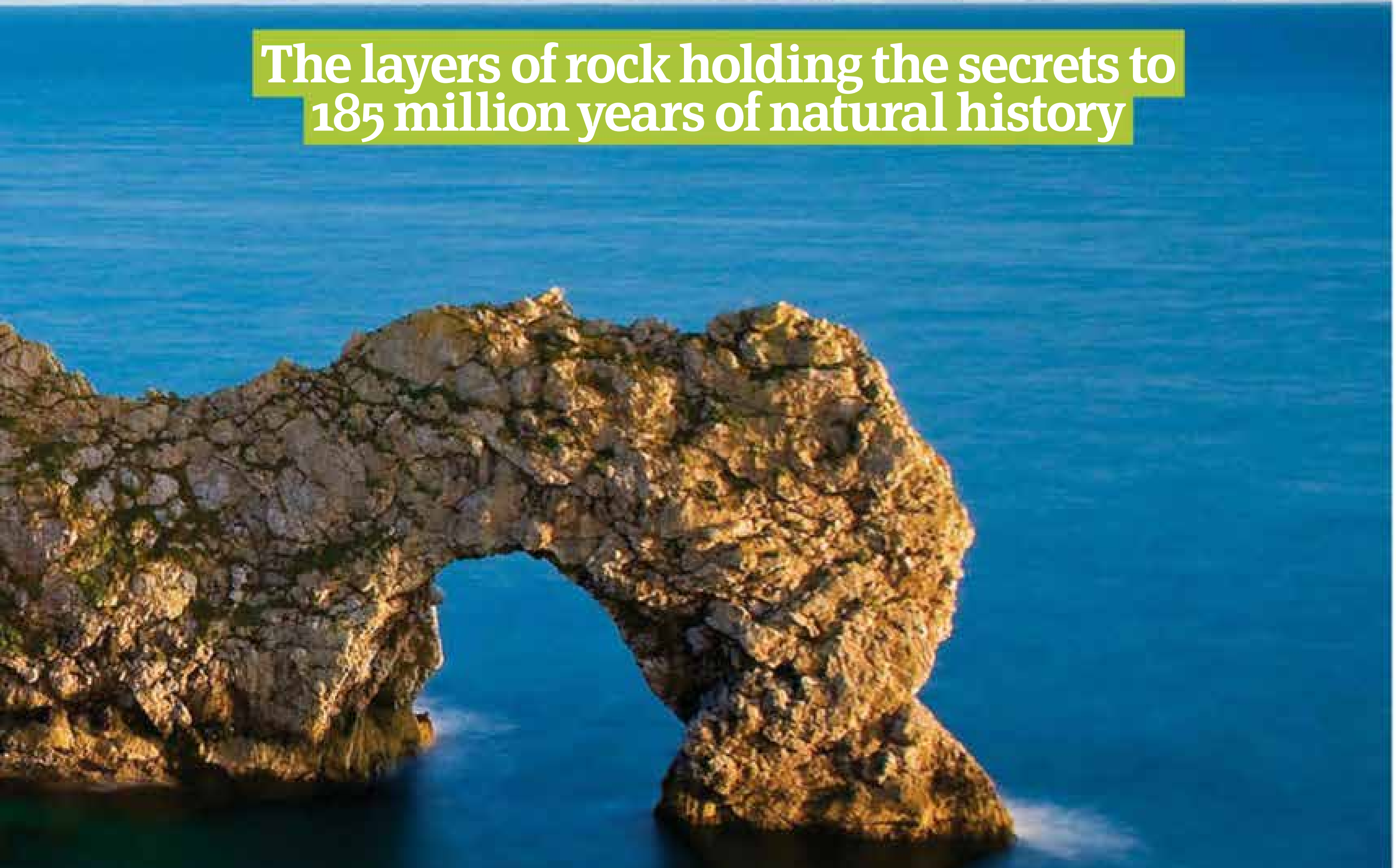
The power of the ocean created Lulworth Cove around 10,000 years ago

> “Animals and plants have been immortalised in the rock as fossils, creating a unique record of prehistoric life”

DID YOU KNOW? *Fossilised droppings are called coprolite and can provide information about what extinct creatures ate*

SSIC COAST

The layers of rock holding the secrets to 185 million years of natural history



The Jurassic Coast is the only place on the planet where 185 million years of the Earth's history is preserved and exposed in layers of rock. Stretching 154 kilometres across the south coast of England, the site is home to spectacular geographic formations and wildlife, and it has been the location of many of the most important fossil finds in scientific history.

Between the dramatic cliffs, secluded coves and magnificent coastal stacks, an immeasurable number of animals and plants have been immortalised in the rock as fossils, creating a unique record of prehistoric life.

Throughout its history the Jurassic Coast has been a desert, a shallow tropical sea and a marshland. Debris from each of these environments has turned into layers of rock, with the oldest rock at the bottom and the youngest on the surface. Over millions of years animals and plants have died here, becoming buried and trapped within the rock layers, which now provide us with a record of life from the Triassic, Jurassic and Cretaceous periods.

As the cliffs have been eroded by the tides over the years, a cross-section of the rock strata has been appeared, allowing us to see the banding of rock from different times. Originally stacked horizontally, tectonic movements have caused the strata to become tilted, which has created a unique 'walk through time' from west to east.

The coast starts with the 250-million-year-old dusty red rocks and ends with 65-million-year-old white chalk cliffs, with fossil-rich Jurassic grey clay and pastel limestone situated in the middle of the coastline. Each part of the coast now serves as a rare snapshot in time, telling pieces of a story through its rock formations and the fossilised remains of the plants and animals that thrived during that period.

A WALK THROUGH TIME

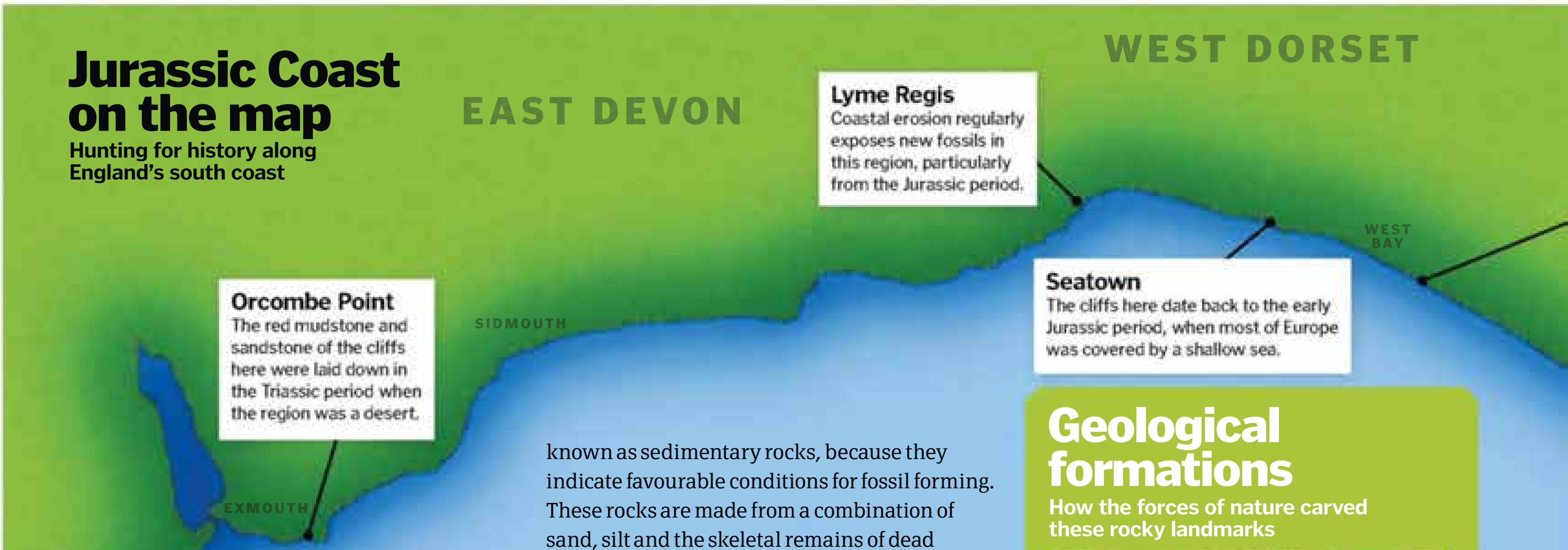
The story starts at the far western tip of Orcombe Point. Made of layers of red mudstone and sandstone first laid down when the coast was a desert at the start of the Triassic period, this desert era was almost completely devoid of life as it followed the largest known mass extinction event, which led to 75 per cent of species on Earth becoming extinct. The catastrophic impact means this area doesn't contain fossils.

The Jurassic Coast then turns to the beautiful banded grey Blue Lias rocks scattered with limestone ledges and green ammonite mudstone. It is in this middle section of the

© Pixabay; Getty; Thinkstock

Jurassic Coast on the map

Hunting for history along England's south coast



Orcombe Point
The red mudstone and sandstone of the cliffs here were laid down in the Triassic period when the region was a desert.

Lyme Regis
Coastal erosion regularly exposes new fossils in this region, particularly from the Jurassic period.

Seatown
The cliffs here date back to the early Jurassic period, when most of Europe was covered by a shallow sea.

Jurassic Coast that you can find beaches abundant in fossils, with different locations hosting different specimens, including dragonflies, shrimps and sharks.

The famous Lyme Regis beach can be found here, with 71 different rock strata identified, each with its own species of ammonite. Other beaches include Seatown, which is bountiful in the fine-grained sandstone known as the Eype Starfish Bed, home to a sea of perfectly preserved brittle stars.

Then there's Burton Bradstock, with its shark fins, echinoids and brachiopods, all waiting to be discovered.

Finally, there are the youngest rocks on the Jurassic Coast, which are situated at the furthest eastern point. This soft, white, crumbly rock is the crushed remains of the skeletons of tiny marine animals from approximately 100 million years ago. In the Cretaceous period the coast was submerged in a warm tropical sea, where an immeasurable number of microscopic plankton swarmed. As these creatures died their skeletons, made from calcium carbonate, gradually accumulated on the seafloor, creating a thick blanket of chalk.

After this time the Mesozoic era came to a dramatic end when a ten-kilometre-wide asteroid plummeted into the Gulf of Mexico, causing cataclysmic devastation that wiped out 75 per cent of all life on Earth. This was the end of the dinosaurs, but it wasn't all doom and gloom. The extinction of the dinosaurs paved the way for new species to evolve, including us.

FINDING YOUR OWN FANTASTIC FOSSILS

FIND THE RIGHT ROCKS

Fossils can only be found in certain rocks, known as sedimentary rocks, because they indicate favourable conditions for fossil forming. These rocks are made from a combination of sand, silt and the skeletal remains of dead animals, and they tend to have formed as a result of rivers, lakes or resting on the seafloor. The good news is the Jurassic Coast contains lots of sedimentary rock, which means lots of fossils.

The types of sedimentary rock you will find on the Jurassic Coast includes shale made from hardened mud, and limestone, which is mostly made from microscopic marine skeletons. When you are looking for your own fossils, make sure that you know there is sedimentary rock in your fossil hunting location.

CHECK THE LAW

In general, if the fossil is still within its original position (either within the cliff or bedrock) then it should not be collected as it could potentially cause damage to the area. Otherwise, in most places you are free to go and hunt for fossils. Make sure that you research the specific area you will be visiting to ensure you are not breaking the law.

STAY SAFE

Always go fossil hunting as the tide is going back out, and be careful not to get too close to crumbling cliffs. Sedimentary rock can collapse quite easily, causing landslides or rocks to fall from the side of the cliff. Remember to tell someone where you are going and take a friend or parent with you, and don't rely on your mobile phone because you might not have any signal when you are on the beach.

> "The Mesozoic era came to a dramatic end when a ten-kilometre-wide asteroid plummeted into the Gulf of Mexico"

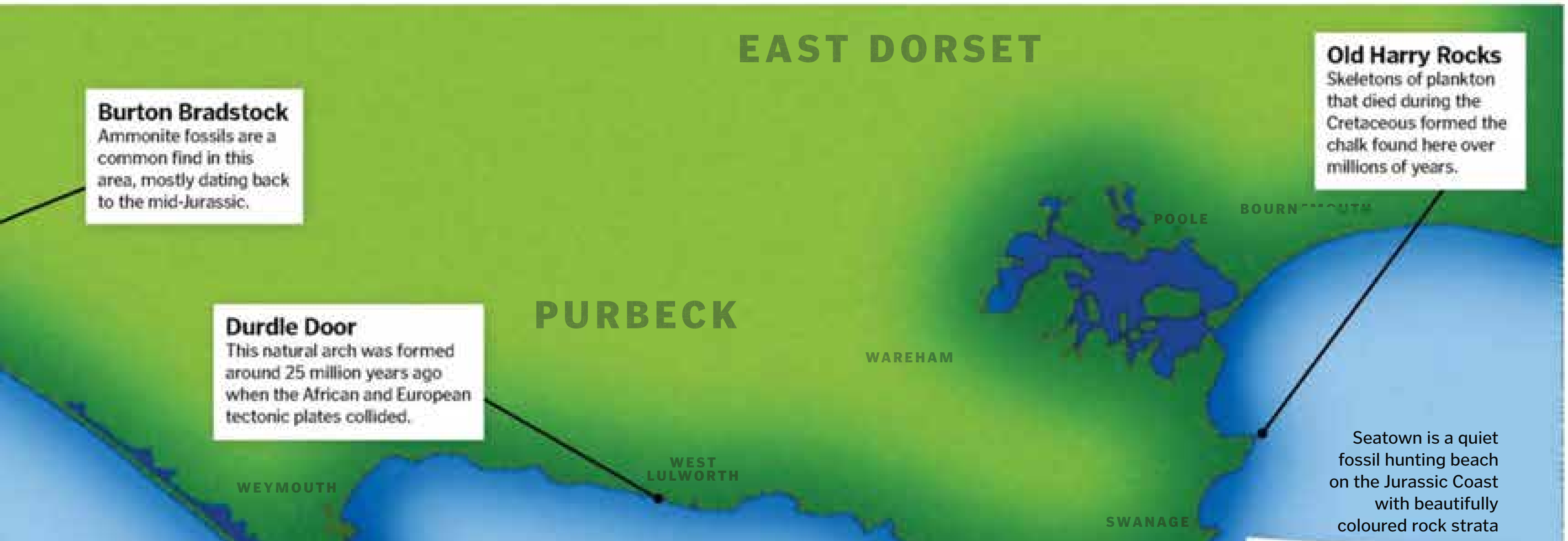
Geological formations

How the forces of nature carved these rocky landmarks

Old Harry's Rock
Old Harry's Rock was once part of a stretch of chalk between Purbeck and the Isle of Wight. The other parts of the stretch have been eroded by the ocean, causing caves and arches to form. Heavy rain and wind caused the collapse of the top of the arches, leaving disconnected stacks of the white rock.

Chesil Bank
This spectacular natural phenomena is a barrier beach — a narrow section of sand that is separated from the mainland by a body of water. Chesil Bank has been rolled by the sea towards the land to join the mainland with the Isle of Portland.

Lulworth Crumple
The concordant and discordant coastline has created movement that is evident in the rocks. The continents crashed together millions of years ago, causing layers of rock to become folded and twisted, eventually buckling under the pressure.



Burton Bradstock
Ammonite fossils are a common find in this area, mostly dating back to the mid-Jurassic.

Durdle Door
This natural arch was formed around 25 million years ago when the African and European tectonic plates collided.

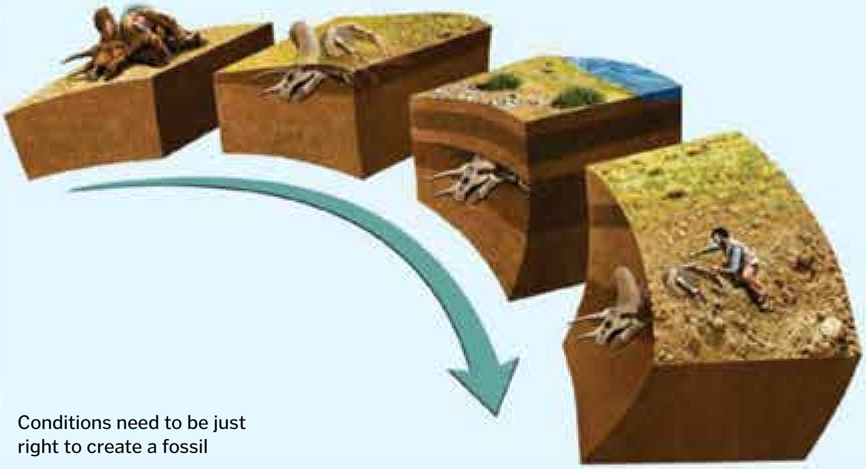
Old Harry Rocks
Skeletons of plankton that died during the Cretaceous formed the chalk found here over millions of years.

Seatown is a quiet fossil hunting beach on the Jurassic Coast with beautifully coloured rock strata

How does a fossil form?

Fossilisation can usually only occur under very specific conditions, somewhere the organism won't get eaten by scavengers. This is more likely to happen when an animal or plant dies in a watery environment like an ocean or a lake. Mud and silt cover the dead organism and over time the soft parts (such as the internal organs, muscle, and skin) decay and rot away. The bones and shells are left behind in the mud. Eventually, the mud is covered with sediment, which hardens into rock. As the trapped bones then start to decay, minerals seep into the space they have left behind cell by cell. This is called petrification. If the bones completely decay, the cavity in the rock left behind can be completely filled with minerals to create a stone replica.

Other fossils can be formed when insects become trapped in tree sap, which hardens and forms amber. Animals can also get trapped in the mix of hot gas and ash that results from a volcanic eruption.



Conditions need to be just right to create a fossil

Finding out all about fossils

From flies to fish, discover how to identify your prehistoric finds

Ammonites

Ammonites are the most common fossils on the Jurassic Coast. They were squid-like animals and their fossils are usually a ribbed spiral shape.

Belemnites

Belemnites were closely related to ammonites. They had large eyes and an ink sac, with hard beaks and tail fins, plus ten arms with hooks to grab prey.

Echinoids

Echinoids have been around for about 530 million years. Many had a hard shell with spines and a beak of five teeth. They can still be found with spines intact.

Fish

Lots of fish can be found on the Jurassic Coast, but they don't resemble those we recognise today because they were covered in a hard enamel shell.

Insects

Around since before the dinosaurs, insects have an external skeleton (exoskeleton), and this is usually the part that is fossilised.

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TAKE EQUIPMENT

If you can get one, use a high-quality splitting tool to crack open rocks. A hammer and cold steel chisel combination is ideal, preferably a large chisel for completing the bulk of the work then a smaller chisel for the finer work and removing the fossil from the rock. If it is not possible to get your hands on this equipment you can just use a hammer. Either way, remember to take goggles to protect your eyes from rock splinters. Other equipment that might be helpful are a pen and paper for labelling your rocks and some plastic bags to store them in. It's also a good idea to record the date and location you found your fossil.

FIND A NODULE

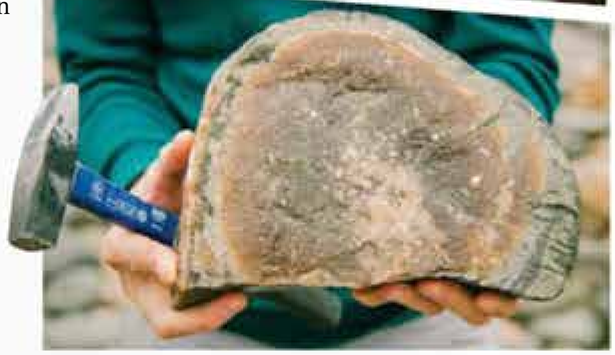
Start looking through the rocks and pebbles beneath the cliff and further towards the ocean. Keep your eyes peeled for regular, round-shaped rocks called nodules. Often you will see nodules with regular lines and patterns on the surface of the pebble that sometimes look like stripes. These will mostly be around the middle. No two nodules are exactly the same, though, so sometimes you might see an ammonite already poking out of the stone or you might see the white zigzags as an edge of a shell starts to show.

Place the nodule somewhere where it can't move and then hit it smoothly and confidently in the middle. It should split open, and with some practice you will be able to learn how to do this in a way that opens the nodule symmetrically and keeps the fossil intact.

AFTER YOU FIND YOUR FOSSIL

So you have made a great fossil find. Now what? It's important to research to see if your fossil is scientifically important. There are lots of databases to do this online. You should also consider if you need to soak your fossil in water to protect it from salt damage. Once you have

Ammonites are a relatively common find along the Jurassic Coast


The best finds come when you start splitting rocks open, like this huge septarian nodule

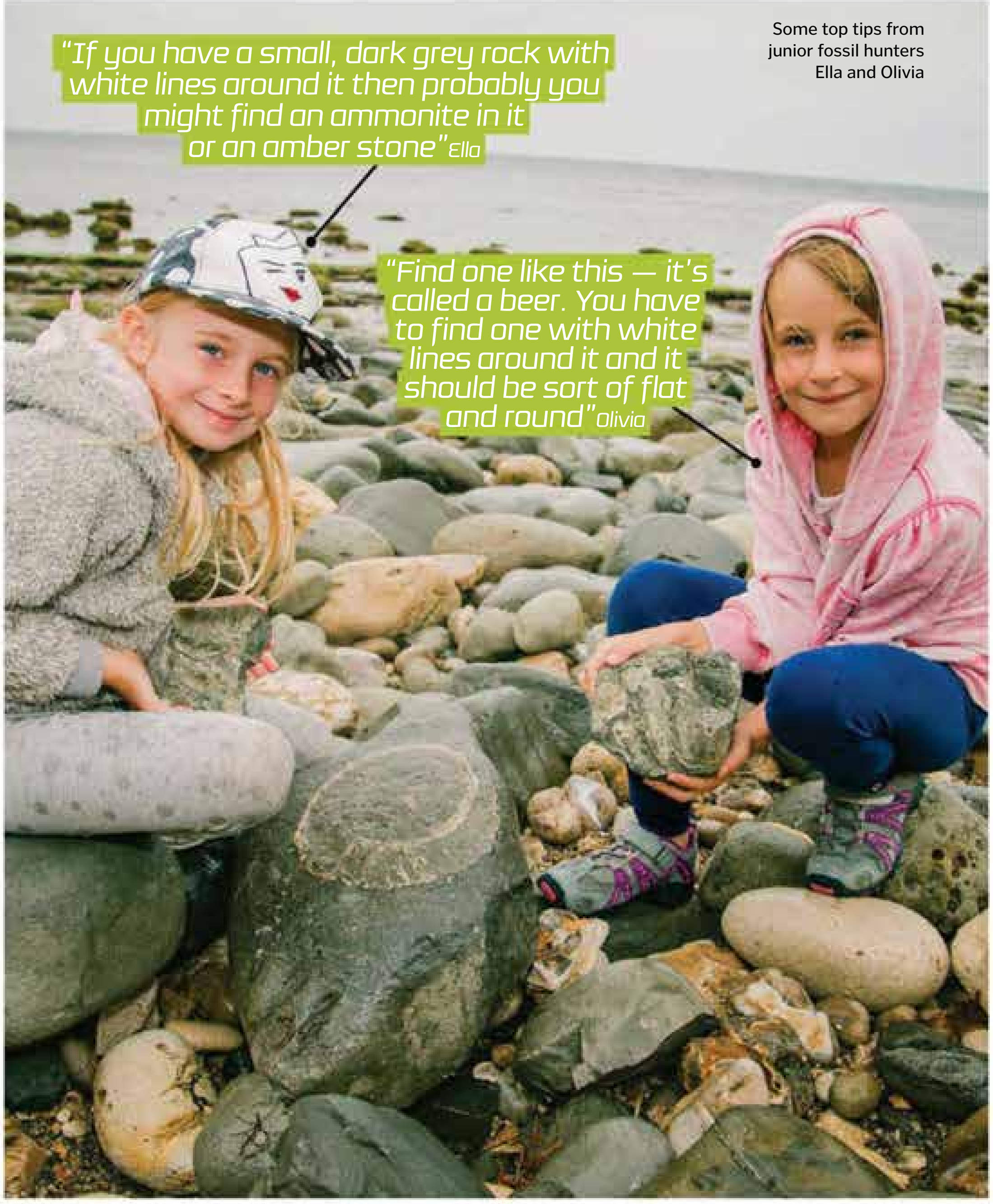
A fossil hunting pioneer

Mary Anning
21 May 1799 – 9 March 1847

Mary Anning was an English amateur paleontologist. She taught herself how to find fossils and became an expert at removing them from the rock without causing damage. She became world famous for her discoveries of Jurassic marine fossils at Lyme Regis. Her work was so significant that it changed the way we understand prehistoric life and the history of our planet.

She would head out in dangerous conditions in the winter looking for fossils after parts of the cliff had fallen away. In 1812, Anning found her most important discovery — an almost complete Ichthyosaurus. She followed this up in 1823 with the discovery of a complete Plesiosaurus. Her work can still be found in museums around the world, including the Natural History Museum in London.

Mary Anning's finds changed our understanding of prehistoric life


Some top tips from junior fossil hunters Ella and Olivia

"If you have a small, dark grey rock with white lines around it then probably you might find an ammonite in it or an amber stone" Ella

"Find one like this — it's called a beer. You have to find one with white lines around it and it should be sort of flat and round" Olivia

DID YOU KNOW? *The oldest dinosaur fossil found to date came from the Nyasasaurus, which lived 240 million years ago*

Q&A with an amateur fossil hunter

Anthony Stonestreet is an 18-year-old Humanities student at Cardiff University who has been fossil hunting in the UK since he was seven

When was the first time you went fossil hunting?
It would have been in the summer of 2006 at Lyme Regis in Dorset. I remember finding a few pieces, they were mainly fragments that I found lying on the beach. We were only passing through and I happened to notice the town's Welcome sign, which has a huge ammonite plastered on it. So we stopped and headed down to the beach.

How often have you returned to Lyme Regis?
Plenty of times! My most recent visit was in March. Not all excursions are successful, though.

Have you had any success on the other beaches on the Jurassic Coast?
I've been to Charmouth — the people in the Heritage Centre are great if you need anything identified. My favourite location on the Dorset coast has to be Seatown, the next hamlet along. It's a mixed bag when it comes to what you might find, but it can yield some really nice fossils.

What have you found in Seatown?
I once found a relatively large ammonite there. Someone had already had a go at it before me, and I just found it as it was on a boulder. I'd say it was about six centimetres in diameter.

What's your best find in the Jurassic Coast?
Probably a pyrite ammonite I found at Charmouth. It was a decent size and so far it hasn't disintegrated — plus it stands out from the rest. I did once find a coral segment at Lulworth Cove; not that big, but it did have an interesting pattern on it. I've found some pretty large belemnite segments and a few whole ones.

How does the Jurassic Coast compare to other sites in the UK?
The Lyme Regis area is one of the most accessible coastal locations in the country, but due to sheer popularity the best finds are gone quite quickly. In comparison, the Yorkshire coast is less well known for its fossils, but compared to Dorset, the locations are harder to access.

Do you have any tips?
For me, finding the best fossil involves going where other people are less likely to have gone before, all the while making sure the area is safe.

When you get to the site, what do you do?
No matter where you happen to go, I think it's best to go when new material is made available. Go on a receding tide and when the cliff is crumbling on a regular basis, not when it's about to collapse in one huge chunk. In either situation, remember to keep a safe distance from the cliff. First of all, I try figuring out where the rubble is or where the scree slopes are. Once I get there, I try to see if I can find loose bits of material at the surface or in large boulders. From there I try to find a smaller piece I can break apart and see what I can find.

Are there any clues to what pieces might contain a fossil? Like a certain shape?
On the Yorkshire coast it'll be round, dark brown/black nodules, which can contain some great ammonites. On the Jurassic Coast it'll be banded pieces of light-grey sediment.

What's your favourite find ever?
That has to be a really large ammonite I found on the Yorkshire coast some years ago. It was about ten centimetres in diameter.

What do you like about fossil hunting?
It's calm; you're often alone on the beach. And you don't know what you're going to find, if anything. There's an element of chance to it.

Any final words of advice for our readers who might want to get started in fossil hunting?
You're more likely to make a good find in winter or after a storm. If you stick to all the safety rules, there's no reason you won't find something.

© Theodore Gray (Nautiloid.net)

With some practice it is possible to crack open rocks perfectly to reveal fossils

Some of Anthony's best finds over the last ten years

The famous chalk sea stacks of Old Harry's Rock

done this you can start using smaller tools to remove the last bits of rock. You could even get a magnifying glass to help do this bit.

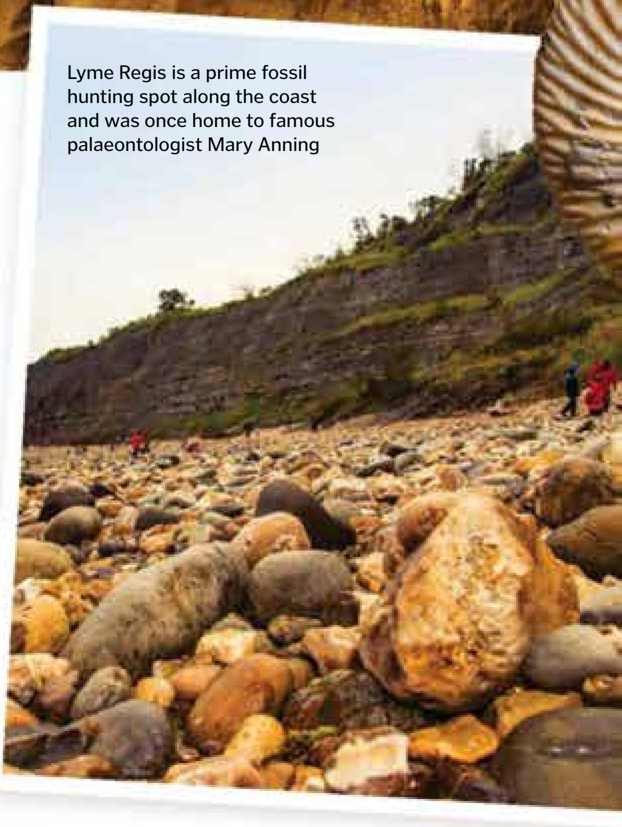
THE HISTORIC BEACHES OF THE JURASSIC COAST

Our team took a day out of the office to visit some of the beaches on the Jurassic Coast. Our first stop was Lyme Regis, which we absolutely loved for fossil hunting. We walked across the beach until we found lots of other people who were looking for fossils. Some were real experts, while others were just trying fossil collecting for the first time, but everyone was working together and comparing their finds with one another.

It didn't take very long before we found some ammonite fossils ourselves. It is a huge beach with beautiful cliffs, and when the tide is out there are plenty of places to look. We didn't crack open any rocks (someone forgot to bring the hammer with them), but we did find huge ammonites just imprinted into the rocks along the shoreline.

If you want somewhere a bit quieter, our favourite beach was Burton Bradstock, which was a much more relaxing environment. It also had a truly stunning display of colourful yellow rock strata. But this beach rewards the patient. We didn't have any luck finding any fossils, but we did notice lots ammonite nodules in the cliff, so there must be a treasure trove buried underneath waiting to be found.

> "Throughout its history the Jurassic Coast has been a desert, a shallow tropical sea and a marshland"



Lyme Regis is a prime fossil hunting spot along the coast and was once home to famous palaeontologist Mary Anning

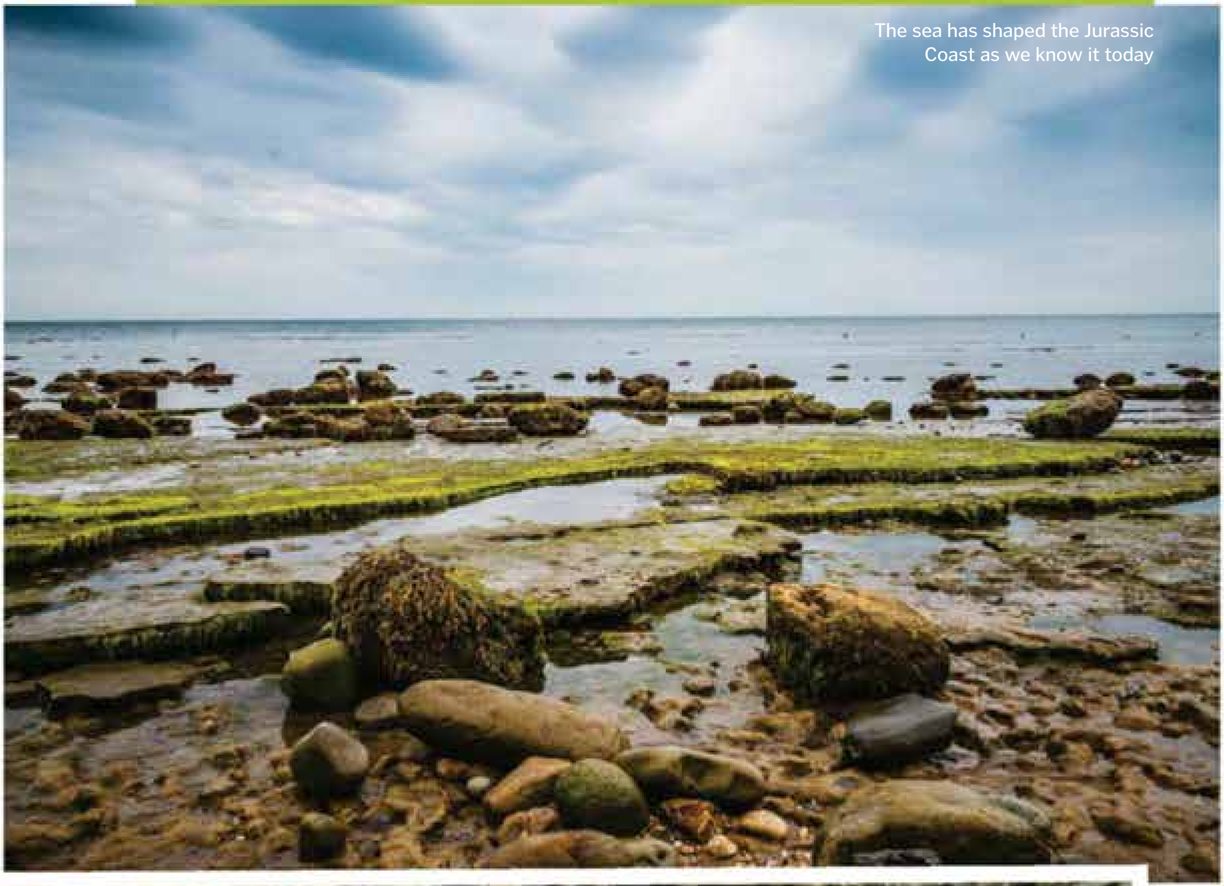
DID YOU KNOW? *The Jurassic Coast was England's first natural World Heritage Site, designated in 2001*

Visitors must take care around the cliffs and look out for safety warning signs, as erosion can lead to rock falls

Conserving the coast

The Jurassic Coast has survived a lot through its history, but now its future depends on us. The biggest threat to its geography and fossils is the ocean and how we choose to manage its effect on the cliffs. Conservation of the site relies on allowing the ocean to continue the natural process of erosion and deposition, as this is what has created the beautiful coastline. However, this same coastline is at risk due to human activity.

If coastal defences such as seawalls are constructed to prevent erosion, they will start to interfere with nature, and in an attempt to stabilise the cliffs, promote the growth of vegetation, which would obscure toe fossils and rock strata. The conservation of the Jurassic Coast will always rely on a balancing act between the ocean and the cliffs, as well as the management of beach litter and shipping traffic.


The sea has shaped the Jurassic Coast as we know it today

Exposed rock strata along the Jurassic Coast reveal millions of years of geological history

© Pixabay; Thinkstock

Hummingbirds

Learn how the world's tiniest birds are uniquely adapted to their roles in specific habitats

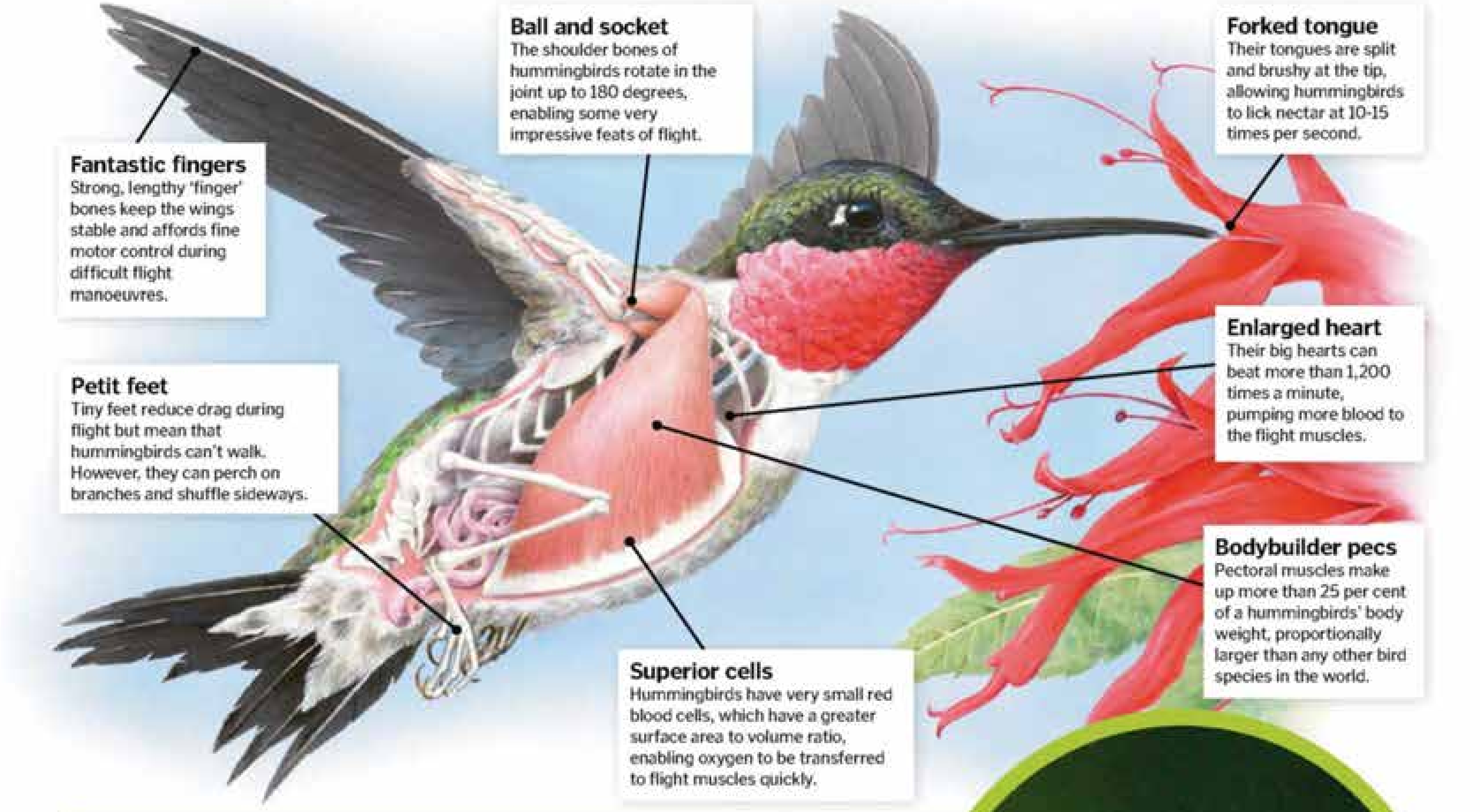
The bee hummingbird is the world's smallest bird at just 5-6cm long and weighing under 2g

Like tiny helicopters flitting among a forest of flowers, hummingbirds are the ultimate hovercraft. In fact, their very name comes from the humming sound created by their rapidly flapping wings. However, all this stationary flight comes at a tremendous cost.

Without nectar to power their high-octane bodies, hummingbirds would starve to death in about two hours. As a result they must spend about 90 per cent of their flying time hovering right beside the flowers upon which they feed. The nectar they consume is essentially sugar water, and they need a lot of it. But it isn't all that they eat. Hummingbirds also snatch up insects such as mosquitos, flies, gnats and aphids. Researchers have found as many as 50 insects in the stomach of a single hummingbird. Suffice it to say, these animals are ravenous. A person using the same amount of energy as a hummingbird would need to scoff 300 hamburgers per day!

Scientists have identified at least 343 different species of hummingbird, which makes them the second largest family of birds in the world. Despite this impressive number, these diminutive birds are only found in North and South America and the Caribbean. Within this range, some species migrate with the seasons for over 800 kilometres. Other species stay put during the entire calendar year.

Hummingbirds are surprisingly aggressive. In countless backyards they lay claim to nectar birdfeeders, chasing away other hummingbirds. And they aren't afraid to pick on someone bigger than themselves either — they commonly attack crows, jays and even hawks if they feel their territory is threatened.



Fantastic fingers
Strong, lengthy 'finger' bones keep the wings stable and affords fine motor control during difficult flight manoeuvres.

Petit feet
Tiny feet reduce drag during flight but mean that hummingbirds can't walk. However, they can perch on branches and shuffle sideways.

Ball and socket
The shoulder bones of hummingbirds rotate in the joint up to 180 degrees, enabling some very impressive feats of flight.

Superior cells
Hummingbirds have very small red blood cells, which have a greater surface area to volume ratio, enabling oxygen to be transferred to flight muscles quickly.

Forked tongue
Their tongues are split and brushy at the tip, allowing hummingbirds to lick nectar at 10-15 times per second.

Enlarged heart
Their big hearts can beat more than 1,200 times a minute, pumping more blood to the flight muscles.

Bodybuilder pecs
Pectoral muscles make up more than 25 per cent of a hummingbirds' body weight, proportionally larger than any other bird species in the world.

How to hover

Kestrels, kingfishers and even ospreys will hover on occasion when hunting prey from above. But none of these other birds have fully mastered the technique in the way that hummingbirds have.

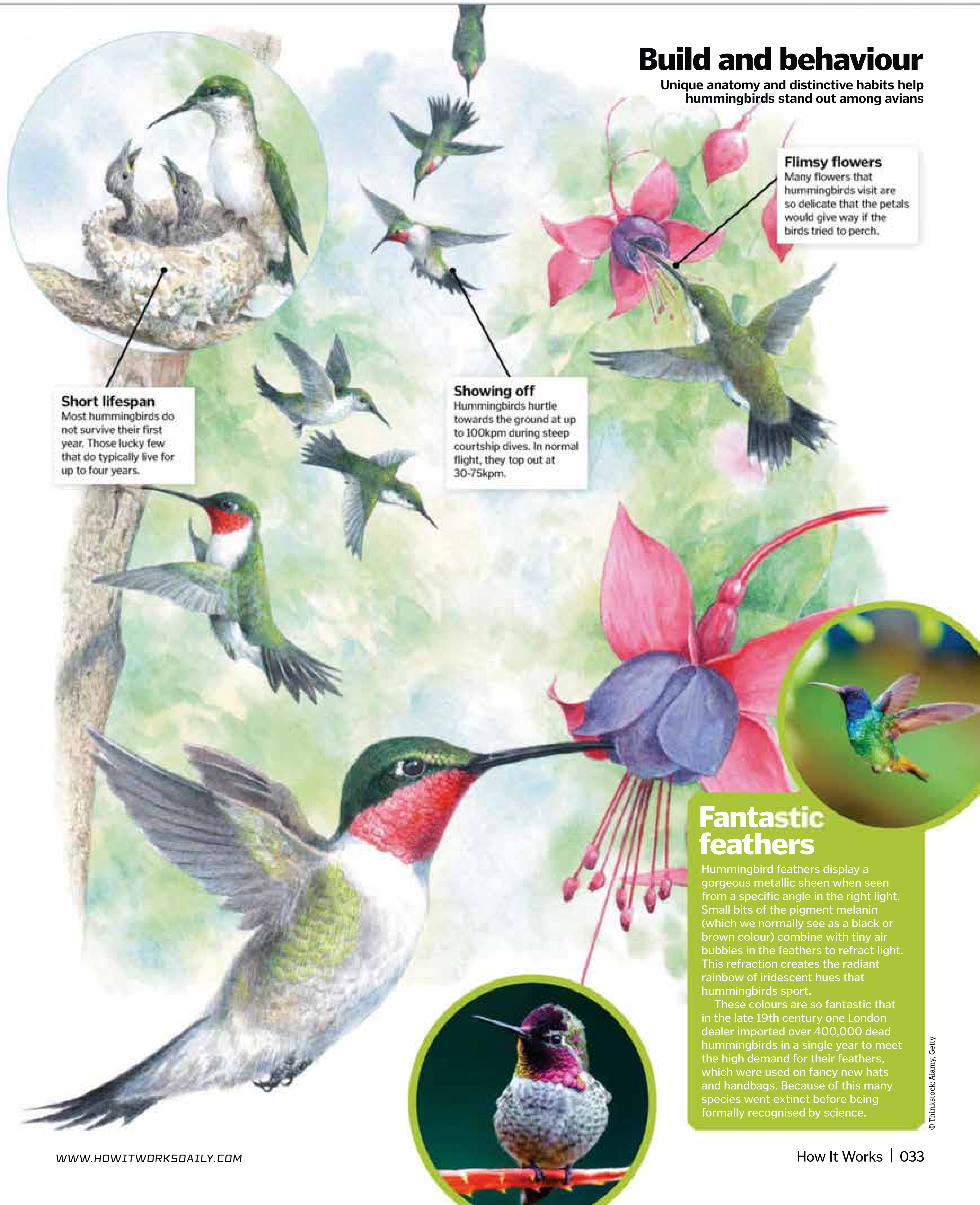
While most birds generate lift and power for forward motion during only the downstroke of their flight pattern, hummingbirds generate lift all the time. They do this by moving their wings forward and backward in a figure of eight pattern, much like a dragonfly.

Hummingbirds can soar forwards, left, right, up and down like any other bird, but they're the only ones that can pilot themselves in any direction. They can fly backwards and upside down, and they even do backward somersaults!

Their unique anatomy is the key to these manoeuvres. Their skeleton is fused in a few places to eliminate the weight of extra muscles, and the bones that they do have are hollow.

Build and behaviour

Unique anatomy and distinctive habits help hummingbirds stand out among avians



Short lifespan
Most hummingbirds do not survive their first year. Those lucky few that do typically live for up to four years.

Showing off
Hummingbirds hurtle towards the ground at up to 100kpm during steep courtship dives. In normal flight, they top out at 30-75kpm.

Flimsy flowers
Many flowers that hummingbirds visit are so delicate that the petals would give way if the birds tried to perch.

Fantastic feathers

Hummingbird feathers display a gorgeous metallic sheen when seen from a specific angle in the right light. Small bits of the pigment melanin (which we normally see as a black or brown colour) combine with tiny air bubbles in the feathers to refract light. This refraction creates the radiant rainbow of iridescent hues that hummingbirds sport.

These colours are so fantastic that in the late 19th century one London dealer imported over 400,000 dead hummingbirds in a single year to meet the high demand for their feathers, which were used on fancy new hats and handbags. Because of this many species went extinct before being formally recognised by science.

© Thinkstock; Alamy; Getty

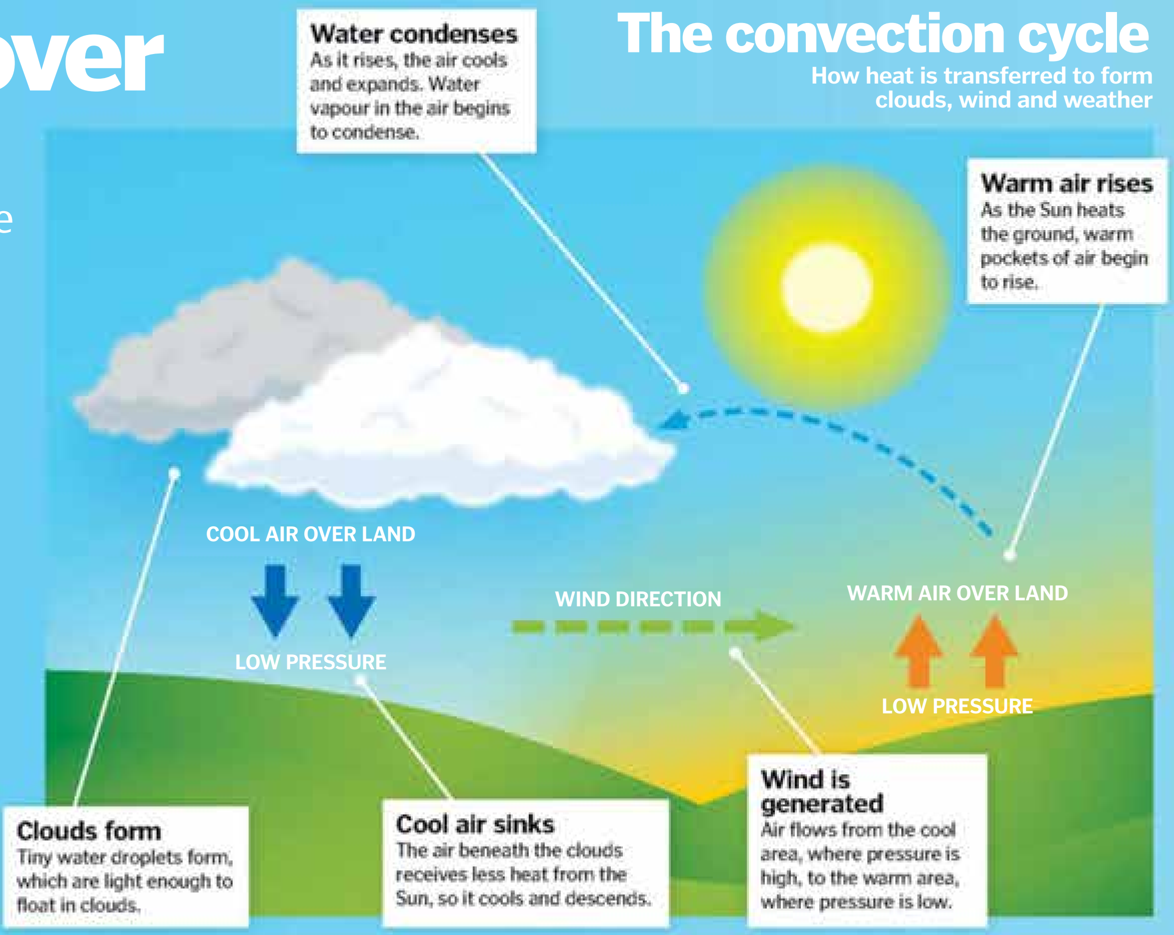
Cloud cover

How puffy pillows of water droplets control the weather from above

While they may seem wispy and weightless, clouds are actually a crucial part of our climate system. At any given time, 70 per cent of the planet is covered in cloud. When air at ground level is warmed by sunlight, it rises and cools, a process known as convection. Water vapour in the air condenses into water or ice droplets, which form clouds. These droplets will gradually combine into larger drops, and then fall as rain or snow. Meanwhile, the cool air descends. At ground level, air flows from cool areas, which are high pressure, to warm areas, which are low pressure, causing wind. Depending on the difference in pressure, this can result in a light breeze or a howling gale.

The convection cycle

How heat is transferred to form clouds, wind and weather



Water condenses As it rises, the air cools and expands. Water vapour in the air begins to condense.

Warm air rises As the Sun heats the ground, warm pockets of air begin to rise.

Clouds form Tiny water droplets form, which are light enough to float in clouds.

Cool air sinks The air beneath the clouds receives less heat from the Sun, so it cools and descends.

Wind is generated Air flows from the cool area, where pressure is high, to the warm area, where pressure is low.

What do bees see?

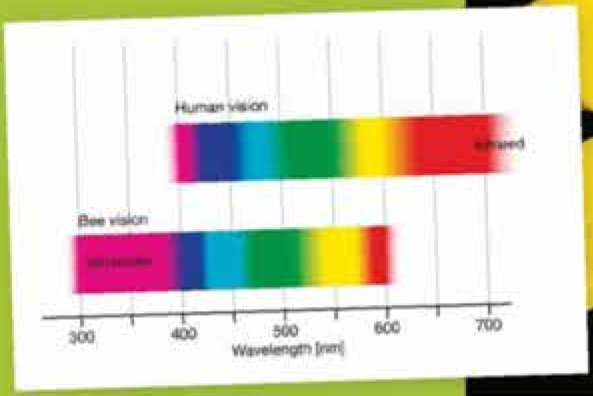
How these flying insects use ultraviolet to make a beeline for nectar

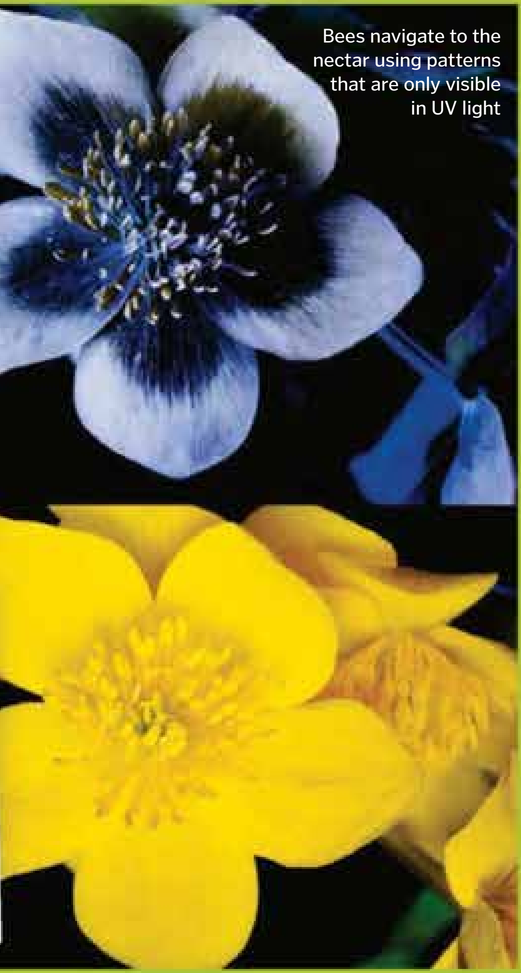
As they swoop over meadows, gardens or parks in search of food, bees see these leafy spaces quite differently to us.

While humans can see red, blue and green light, bees detect blue, green and ultraviolet (UV) light instead. With this altered vision, flowers stand out much more clearly against foliage, and some even feature UV 'landing strips' that guide the bee towards their nectar. These UV patterns form concentric circles or dots in the centre of the flower, which highlight the best places to search for food. This helps to pollinate the flowers, as bees pick up pollen and distribute it at their next stop. However, some spiders are known to hunt bees by using UV patterns on their bodies or webs, which confuse the insects and lure them into danger.

If they do escape this deception, bees can use another quirk of their vision to navigate home. Air molecules in our atmosphere scatter to form a pattern of polarised light at a right angle to the direction of the Sun. While this goes unnoticed by humans, it is visible to bees, and they can use it to plot their position even when it's cloudy.

> "Some plants feature a 'landing strip' to guide bees to their nectar"




Bees navigate to the nectar using patterns that are only visible in UV light

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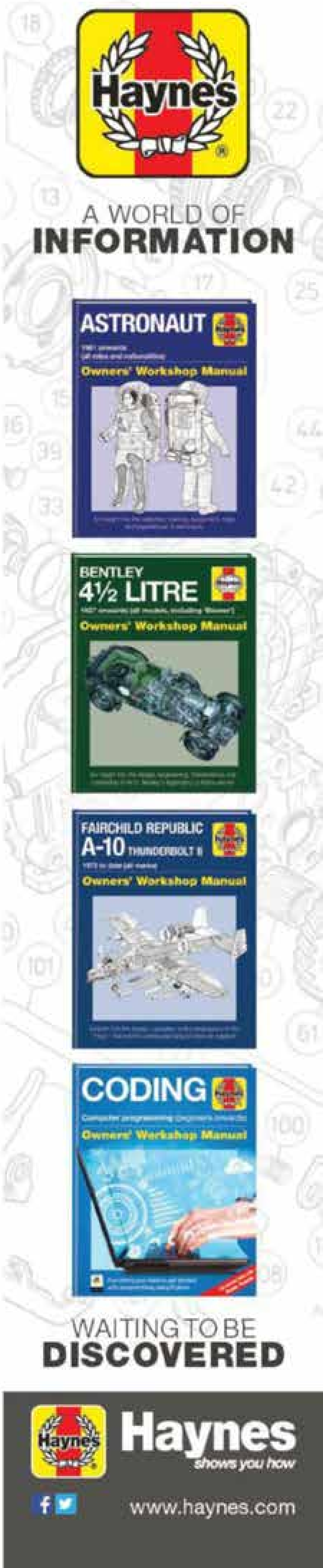
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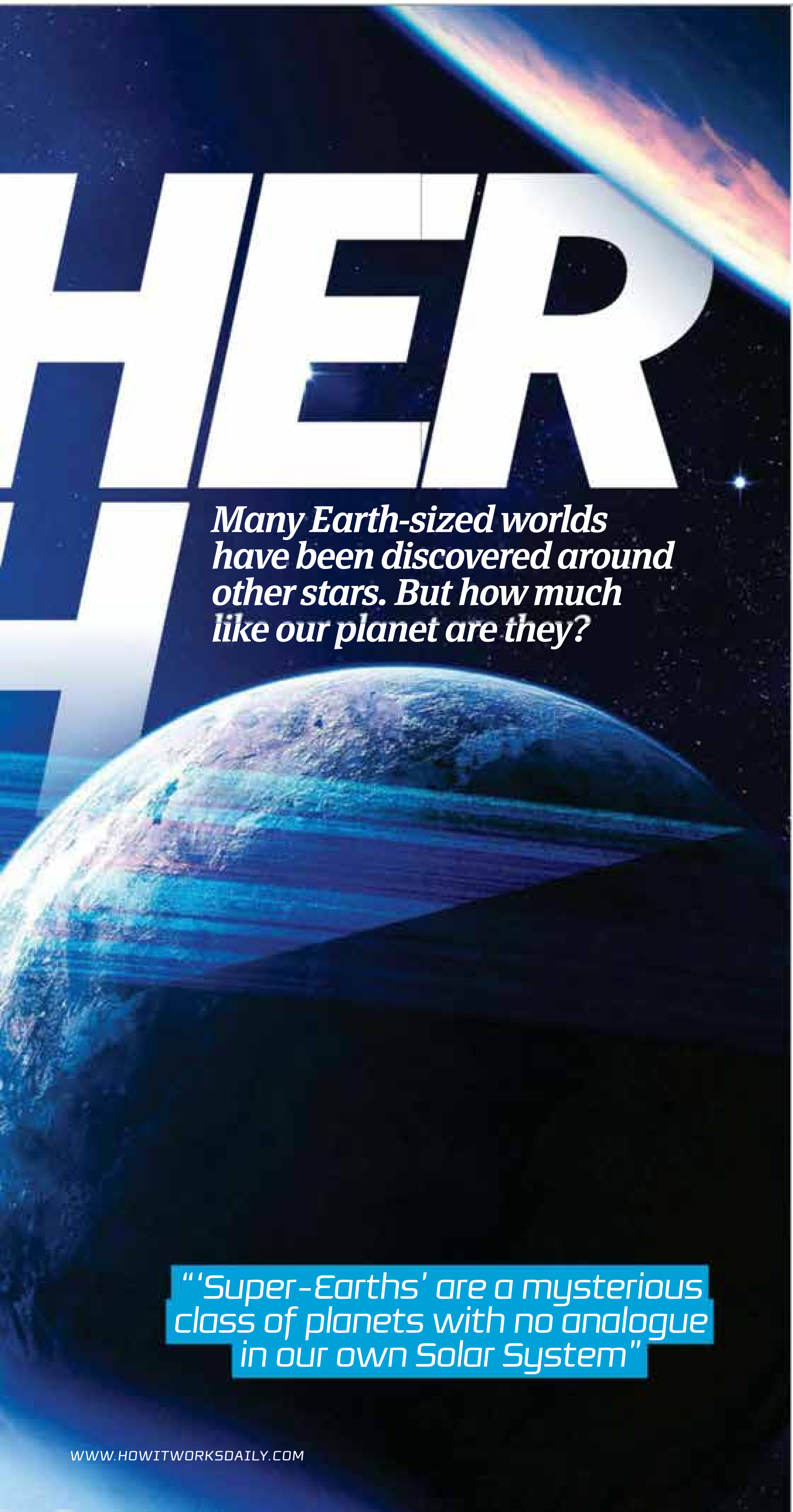


Many Earth-sized worlds have been discovered around other stars. But how much like our planet are they?

> "'Super-Earths' are a mysterious class of planets with no analogue in our own Solar System"

In the constellation of Cancer the Crab is a distant sun orbited by five planets. Just visible to the naked eye, this star is the same size as our Sun and is surrounded by planets that range from more massive than Jupiter to close to the size of Earth. Yet this is not a copy of our own Solar System. In fact, it hosts one of the most alien worlds imaginable.

The star is known as 55 Cancri, a Latin name that is derived from the constellation in which it sits. The planets are denoted with the addition of a lowercase letter starting from 'b' in the order that they were discovered. 55 Cancri e is therefore the fourth planet to be found around the star 55 Cancri.

The five planets in this system were discovered by observing a slight wobble in the star's position due to the gravitational tug of the orbiting planets. This is known as the 'radial velocity' or 'Doppler wobble' technique. The magnitude and frequency of the star's wobble provides information about a planet's mass and the duration of its orbit about the star. This told astronomers that the innermost and smallest world was 55 Cancri e, weighing in at just eight times the mass of the Earth.

The measured mass of 55 Cancri e made it a 'super-Earth', a mysterious class of planet with no analogue in our own Solar System. The planets around our Sun are divided into two distinct types: the rocky worlds like the Earth and Mars with thin atmospheres over solid surfaces, and the gas giants such as Jupiter and Neptune whose solid cores are enveloped in crushing gases tens of thousands of kilometres deep. With a mass in between our largest rocky planet, the Earth, and our smallest gas giant, Neptune, the nature of a super-Earth is unclear. So was 55 Cancri e a super-sized rocky world or a mini gaseous one?

One way to resolve this conundrum is to measure the planet's physical size. With both the mass and size, the average density of the planet can be computed. A low density around 1.3g/cm^3 (grams per cubic centimetre) would indicate a planet whose volume is largely atmosphere, while an Earth-like 5.5g/cm^3 value would suggest a world of mainly rock.

Planet size cannot be found from the wobble in a star's position, but it can be measured if a

MEET THE EXPERT

Elizabeth Tasker is an astrophysicist at the Japan Aerospace Exploration Agency (JAXA). Her research uses computer models to explore the formation of stars and planets.

© Alamy

dip in the starlight is detected. If the planet crosses the star's surface as viewed from Earth there will be a tiny drop in brightness as the planet obscures part of the star. Known as the 'transit' technique, it has been used alongside the radial velocity technique find 96 per cent of the exoplanets we know of today.

Measuring both planet mass and size is not easy. Not all planets transit and detecting the influence of a tiny world around its much larger star is always challenging. But with 55 Cancri e, astronomers got lucky. NASA's Spitzer Space Telescope spotted a characteristic light dip matching the orbit of the super-Earth. 55 Cancri e turned out to be 20 per cent larger than the Earth. This made it… actually, it still was not clear.

> "Each possibility paints a picture of a wonderfully horrifying world"

The average density of 55 Cancri e is 4g/cm^3, a value too high to be a gas giant and too low to be a rocky world. What kind of planet could have such an intermediate density? Theories sprang up and each paints a picture of a wonderfully horrifying world.

The first option is that 55 Cancri e is a hybrid planet, with a rocky surface like the Earth but a much thicker atmosphere. The higher mass of 55 Cancri e would give the planet stronger gravity than the Earth. This could be enough to hold onto light gases such as hydrogen and helium. The Earth's gravity was too weak to retain these gases in our air, but they form most of this gas giants' atmosphere. If just 0.1 per cent of the planet's mass was in these light elements the planet's size would expand to give an average density matching that of 55 Cancri e.

A hybrid world seems like a convincing solution, but it has one problem. 55 Cancri e sits incredibly close to its star, taking just 18 hours to complete one orbit. By contrast, the innermost planet of our Solar System is Mercury, with an orbit of 88 days. The close proximity of the nuclear inferno of the star results in an average planet temperature of 2,000 degrees Celsius. Such blistering heat should be able to burn away the light gases to leave a much thinner atmosphere or none at all. So if a thick atmosphere is unlikely, what else could explain the planet's low density? One option is a peculiar form of water.

While liquid water could not remain on a planet hotter than Mercury, water could exist in a phase known as 'supercritical'. Such fluids are found at very high temperatures and pressures, such as rocket fuel during a launch. Supercritical water is neither liquid nor steam but something in between. If you visited a supercritical water world you would be suspended in fog, unable to tell where the ocean met the sky.

A third explanation for the density of 55 Cancri e is that the planet has a mantle made of diamond. While the star 55 Cancri is similar in size to our Sun, its composition is rich in carbon. Since the same mix of dust and gas build both the star and the planets, a carbon-rich star is expected to be orbited by carbon-rich planets.

Although carbon is a major constituent for biological life, just 0.2 per cent of the Earth's mass is carbon. This tiny fraction is due to carbon only being condensed into a solid in the cold outer reaches of the Solar System where the gas giants were forming. Near the Earth's location, carbon was a vapour and the planet-forming grains were made from silicates and iron. However, if the fraction of carbon increases, it can begin to replace oxygen and bond with silicon. The result is rocks of silicon-carbide rather than the silicate on Earth.

A planet with rocks of carbon and silicon instead of oxygen and silicon could have a mass

Venus receives less than twice the radiation from the Sun than Earth, but its thick atmosphere gives a surface temperature capable of melting lead

The first exoplanet discovery

The first exoplanets discovered were not orbiting a star like our Sun. Instead they circled a dead star called a pulsar. A pulsar forms when a star more massive than our Sun reaches the end of its life and explodes in a supernova. The remnant is an incredibly dense ember the size of a city but around twice as massive as the Sun.

Pulsars emit incredibly powerful jets of radiation that we can see on Earth. If the pulsar is part of a binary star system, the jets can sometimes blowtorch the stellar sibling to pieces. The shredded star forms a disc around the pulsar from which a new generation of planets can be born.

The Trappist-1 worlds

Seven Earth-sized planets were discovered this year orbiting the star, Trappist-1. So could any of them be like Earth?

Evidence suggests the planets may have formed far from their star and moved inwards. If true, these worlds may be the stripped cores of gas giants and packed with ice. But could an ice and silicate composition still create a protective magnetic field?

Different greenhouse gases in the air may produce hotter or colder lands. There may be no land at all if the ice melts into a global ocean, or alternatively, the water may be evaporated away by the star's radiation.

Until we can glimpse the atmosphere of these planets we won't know how Earth-like or alien they may be.

An artist's concept of the possible surface of TRAPPIST-1 f

DID YOU KNOW? *NASA's Kepler Space Telescope has found nearly 2,500 confirmed planets using the transit technique*

An artist's concept of the first exoplanets that were discovered around a pulsar

The exoplanets Kepler 70b and Kepler 70c are thought to have survived within their host star's envelope during it's red giant phase

An artist's concept of Kepler-452 b, which orbits in the habitable zone. However, this does not mean the planet is like Earth

© NASA/JPL-Caltech/Ames/JPL-Caltech/T. Pyle; ISAS/JAXA; Ron Miller NASAblueshift

and radius that matches 55 Cancri e. Rather than supercritical water, such a planet may not have any water at all.

When carbon is in plentiful supply oxygen will bond with it to form the toxic carbon monoxide. This leaves much less oxygen to bond with hydrogen and form water. The entire planetary system might therefore be entirely dry. Therefore, even if 55 Cancri e orbited further from the star, as a carbon world it would still possess an uninhabitable landscape.

A carbon planet would have a crust of graphite that turns to diamond deeper below the surface. Lakes would be of liquid tar and the air would be a smog of carbon monoxide and dioxide. The blackened graphite surface would absorb heat, creating a world far hotter than the Earth even at the same distance from the star. And this is the more optimistic picture.

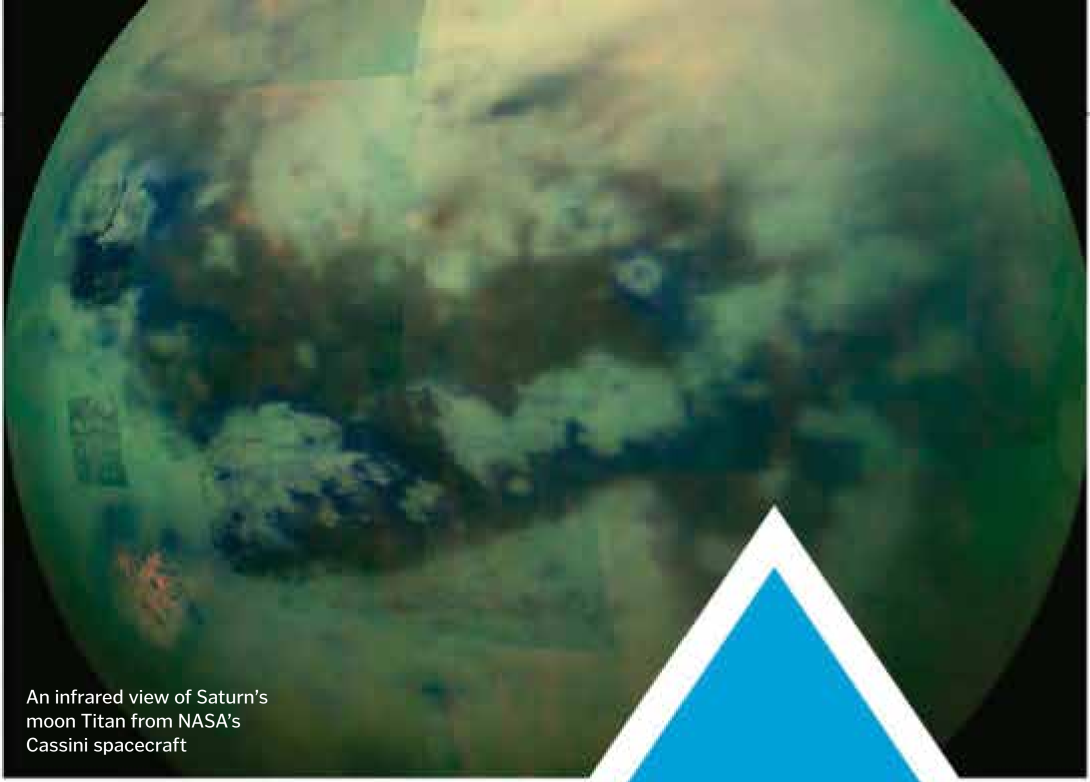
The geology of a carbon world would likely be very different from the Earth. Our crust is broken into tectonic plates that shuffle around to produce volcanos and support our magnetic field. With a less pliable diamond interior, the carbon world might have a stationary crust. This could kill the magnetic field, leaving the planet vulnerable to sterilising flares from the star. Without volcanism ejecting heavy gases that can be held by the planet's gravity, an Earth-sized carbon world might lose its atmosphere entirely.

These three scenarios for 55 Cancri e tell us something very important about exoplanets: an Earth-sized planet does not necessarily mean Earth-like conditions. Mass and size alone are not enough to confirm what it would be like on the surface of a seemingly similar planet.

This knowledge is key to understanding discoveries of planets in the so-called habitable or 'Goldilocks' zone; the region around a star where a planet receives a similar amount of radiation to the Earth. Unless the planet is an exact Earth clone, this location does not mean that the planet surface is suitable for liquid water. A higher mass could trap a thick atmosphere and raise the surface temperature to the lead-melting conditions found on Venus.

A different rock type could lead to no atmosphere at all or prevent the formation of a protective magnetic field. Even an Earth-sized world in the habitable zone might therefore be as barren and inhospitable as a planet as hot as 55 Cancri e.

This might seem a gloomy prospect for finding another home world, but the next generation of telescopes is aiming to change our perspective by examining the planet's atmosphere. As starlight passes through the atmosphere of a planet, different molecules in the air absorb particular wavelengths of light. The missing light forms a distinctive fingerprint that can reveal what gases are present. Since the atmosphere composition is affected by geological and surface processes, this will be the first probe of the planet's surface environment. The right molecules in the air may even hint at the presence of life.



An infrared view of Saturn's moon Titan from NASA's Cassini spacecraft

Super-Earths like CoRoT-7 b sit in between the Earth and Neptune in size

But what about conditions on 55 Cancri e? New measurements last year suggested yet another scenario for this bizarre world. The Spitzer Space Telescope measured the heat emitted from the planet and discovered it fluctuated by nearly 2,000 degrees Celsius. Moreover, the dip in starlight was not consistent between transit observations, suggesting the planet was somehow changing in size.

> "An Earth-sized planet does not necessarily mean Earth-like conditions"

The proposed explanation is a volcanic world. If 55 Cancri e is a rocky planet then the intense heat from the very close star would melt the surface into a molten magma. On such a lava world, volcanos could easily spew plumes of melted rock up into the atmosphere.

If the thick volcanic ash rose high enough, the planet's radius would seem to expand and the cooling plumes would suggest a lower planet temperature. As the eruptions subsided, the hotter lower regions of the planet's atmosphere would again become visible.

A glint of life

What atmosphere gas would suggest an inhabited planet? Life on Earth produces both oxygen and methane. The problem is both these molecules can be formed by non-biological processes.

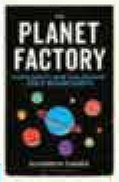
Ultraviolet radiation from the star can break apart water molecules in the atmosphere into oxygen and hydrogen. The light hydrogen can escape an Earth-sized planet to leave an oxygen-rich air.

Saturn's moon Titan has an methane-rich atmosphere but no signs of life. Large methane reservoirs beneath Titan's surface eject methane into the atmosphere via icy volcanos.

A better biological signature is a combination of gases. Since oxygen and methane combine to form carbon dioxide, the presence of both in an atmosphere may suggest life is continually replenishing these molecules.

If the smaller size measured for 55 Cancri e reflects the planet's true dimensions, then an Earth-like silicate composition can match the planet's properties. But this does not rule out a carbon or supercritical water world.

Whatever the composition of 55 Cancri e turns out to be, this Earth-sized world approximately 40 lightyears away from our Solar System is not remotely Earth-like in any way.

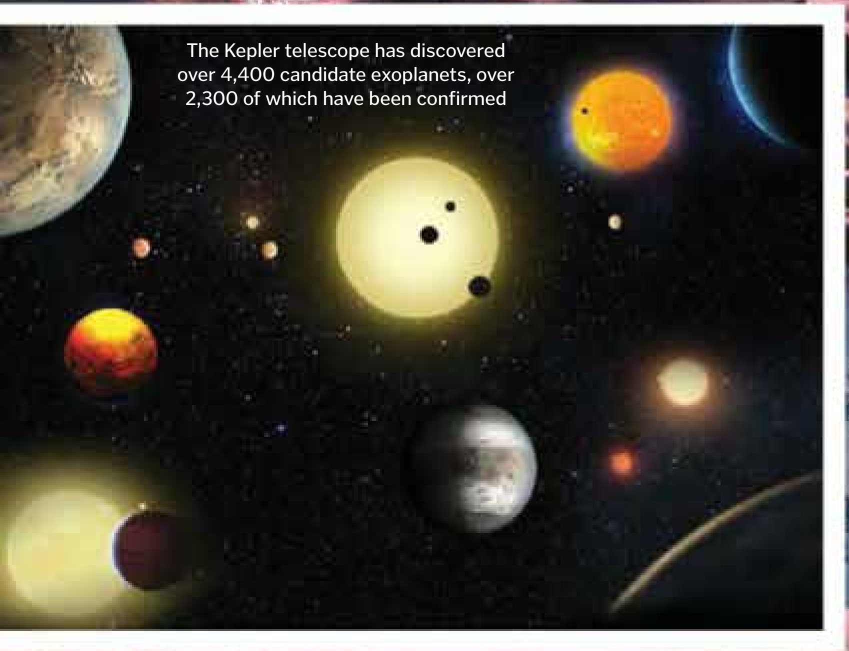


Learn more

Discover more incredible exoplanets and alien landscapes in Elizabeth's new book: *The Planet Factory: Exoplanets and the Search for a Second Earth*, out now published by Bloomsbury Sigma.

DID YOU KNOW? *Future missions to detect exoplanet atmospheres include NASA's JWST and the UK's Twinkle telescopes*

The barren surface of a Trappist-1 planet



The Kepler telescope has discovered over 4,400 candidate exoplanets, over 2,300 of which have been confirmed

© WIKI/Aldaron; NASA/JPL/University of Arizona/University of Idaho; ESO/M. Kornmesser

GigaGalaxy Zoom

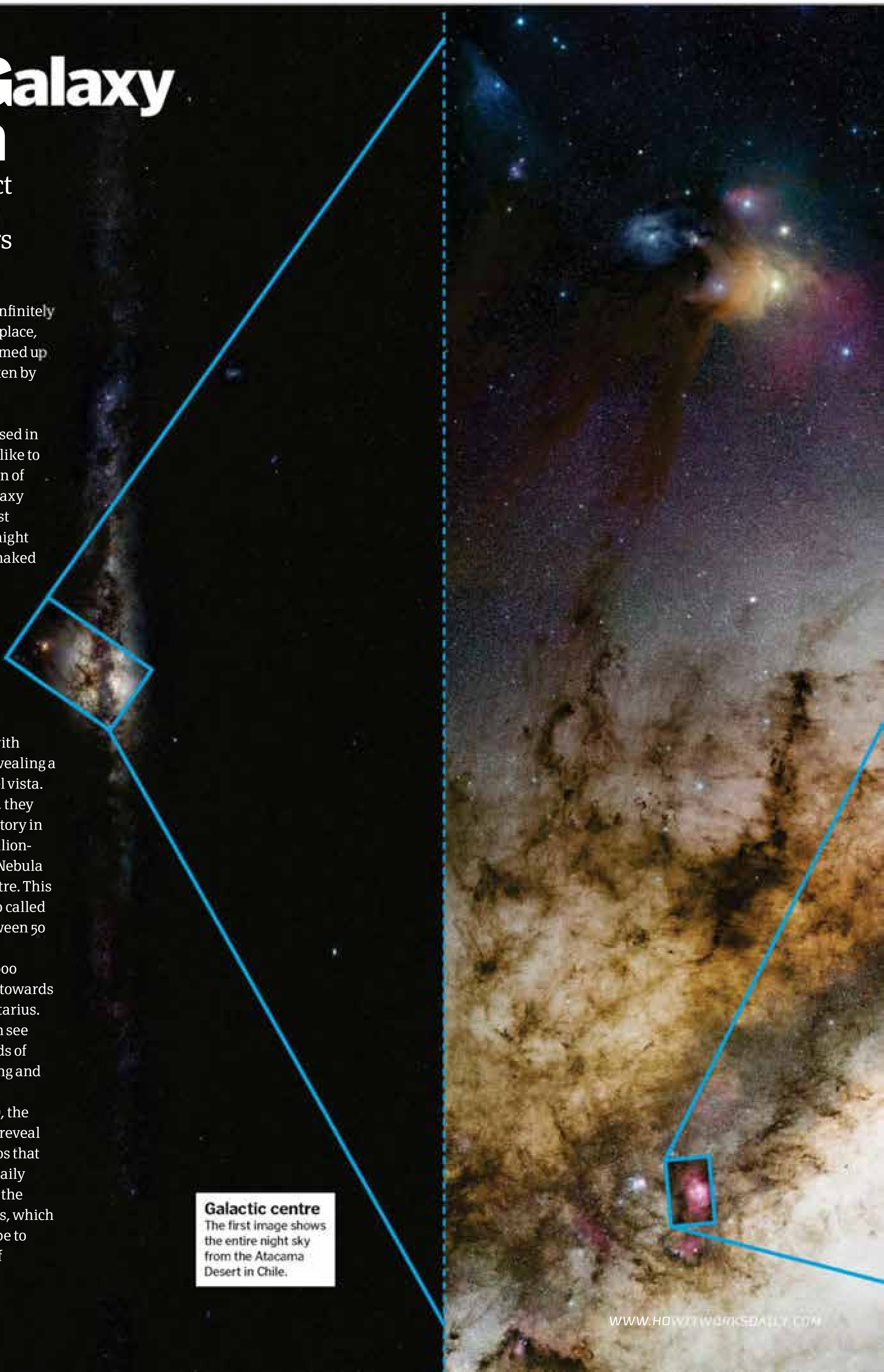
How this project revealed the hidden wonders of the cosmos

The universe is an infinitely vast and fantastic place, perhaps best summed up in these three images taken by the European Southern Observatory (ESO).

These shots were released in 2009 to show what it was like to zoom into a specific region of space. Called the GigaGalaxy Zoom project, the ESO first showed what the entire night sky looked like with the naked eye by releasing an 800-million-pixel panorama taken from Chile's Atacama Desert. In the second part of the project, they zoomed into the galactic bulge of our Milky Way with an amateur telescope, revealing a glorious 340-million-pixel vista.

In the final instalment, they used the La Silla Observatory in Chile to capture a 370-million-pixel view of the Lagoon Nebula towards our galaxy's centre. This young stellar cluster, also called NGC 6530, is home to between 50 and 100 stars across 100 lightyears. It's located 5,000 lightyears away from us, towards the constellation of Sagittarius. Inside the nebula you can see dark patches where clouds of dust and gas are collapsing and forming into new stars.

In the words of the ESO, the goal of the project was to reveal the "deep, 'hidden' cosmos that astronomers study on a daily basis". It's reminiscent of the Hubble Deep Field images, which used the Hubble Telescope to reveal the vast number of galaxies in our universe.



Galactic centre
The first image shows the entire night sky from the Atacama Desert in Chile.

DID YOU KNOW? *There are 2 trillion galaxies in the observable universe, ten times more than was previously thought*

Galactic bulge
The second image shows the centre of our Milky Way as seen through an amateur telescope.

> *"Dark patches in the nebula reveal where clouds of gas and dust are collapsing"*

Lagoon nebula
The third image shows the glorious Lagoon Nebula towards our galaxy's centre.

© ESO/S Guisard/S Brunier

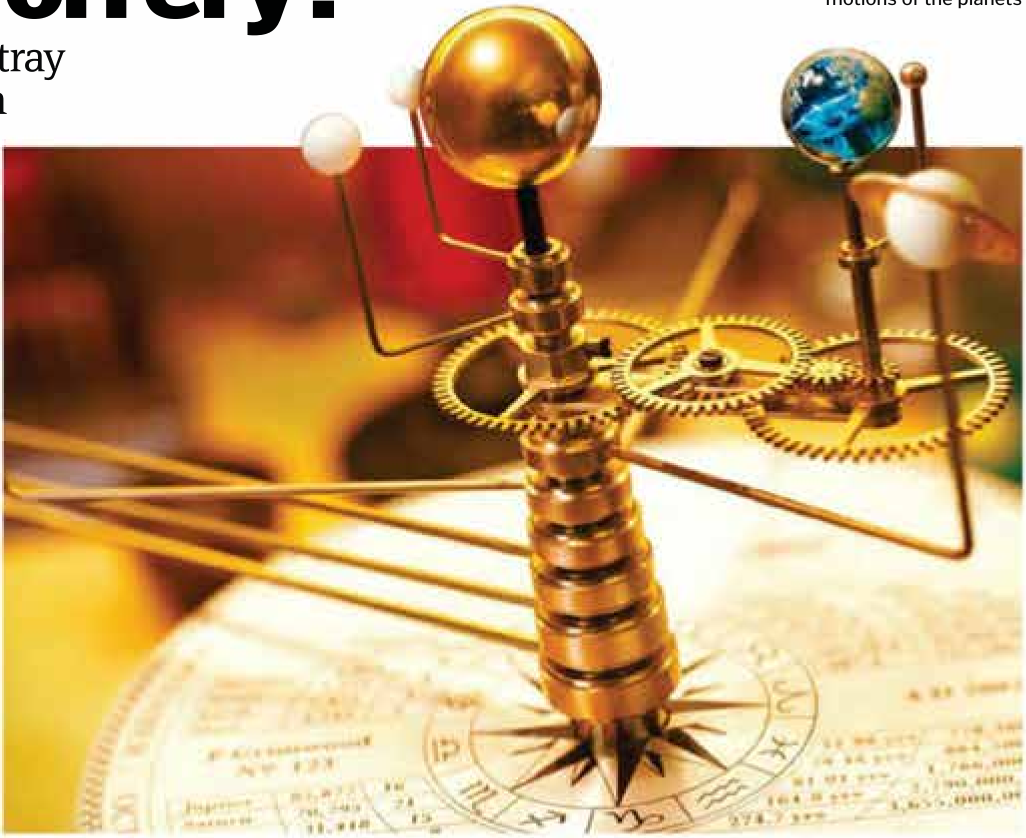
What is an orrery?

How these historic models portray the planets in our Solar System

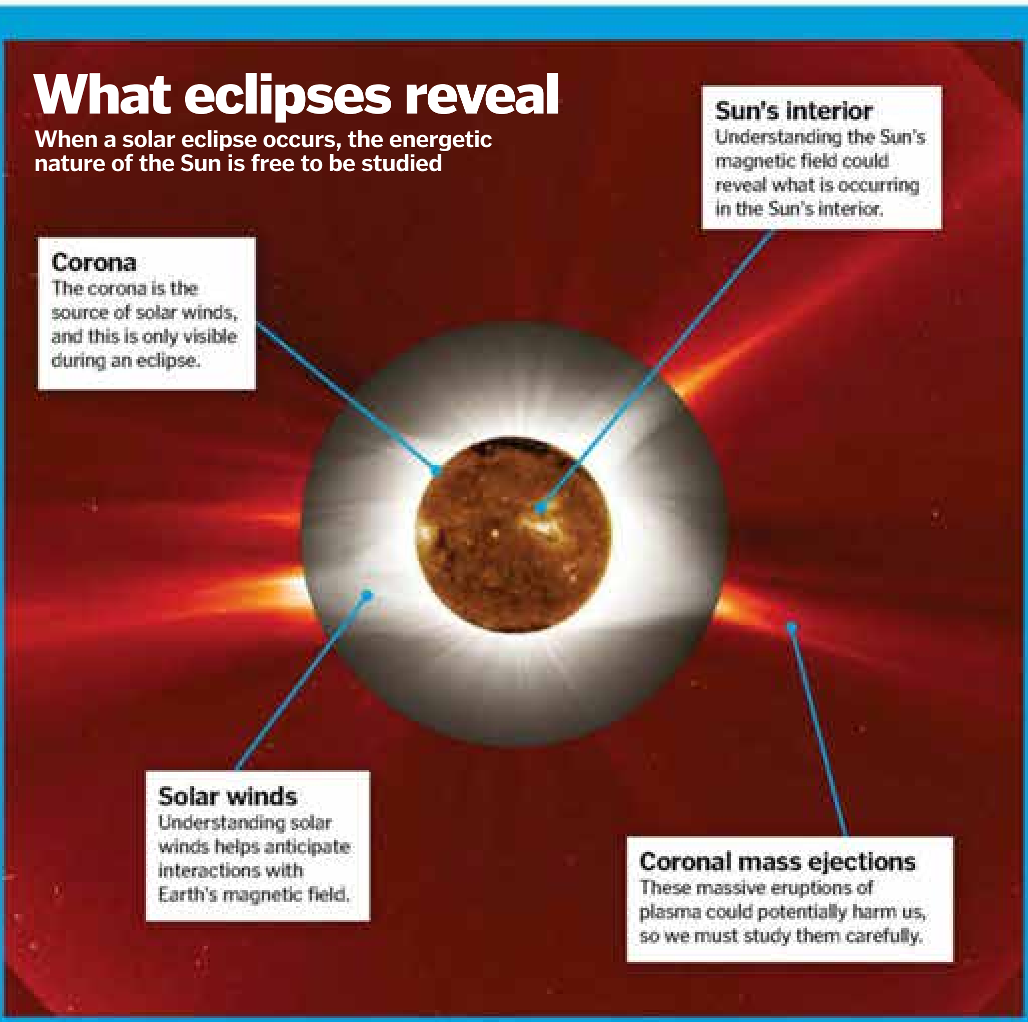
In 1704, Charles Boyle, the fourth Earl of Orrery, was presented with a mechanical model of the Solar System. This was the first model of its kind and was henceforth known as an orrery.

A typical orrery is a series of 'planets' — normally represented by different sized globes — separated by different length arms. These arms originate from the central 'Sun' and are then propelled by a clockwork mechanism. This particular model is primarily used as an educational tool, as it can show the relative sizes, distances and motions of the planets and the Moon in our Solar System.

A modern orrery consists of a heliocentric model, with the eight planets, the Moon and possibly Pluto, depending on the year of its construction. This educational tool can provide a visual explanation for different astronomical events in our Solar System, such as how an eclipse occurs, why Neptune takes longer to complete one orbit than Mercury, or even the retrograde motion of Mars in our night sky.



A series of gears, identical to clockwork, simulate the motions of the planets



What eclipses reveal

When a solar eclipse occurs, the energetic nature of the Sun is free to be studied

Sun's interior
Understanding the Sun's magnetic field could reveal what is occurring in the Sun's interior.

Corona
The corona is the source of solar winds, and this is only visible during an eclipse.

Solar winds
Understanding solar winds helps anticipate interactions with Earth's magnetic field.

Coronal mass ejections
These massive eruptions of plasma could potentially harm us, so we must study them carefully.

Studying the Sun's corona

How can a solar eclipse reveal the mystery of the Sun's outer layers?

When a total solar eclipse occurs, scientists use these precious minutes to study the Sun's elusive corona. The corona is an area of hot, energetic plasma that encompasses our Sun and other stars. The Sun's photosphere — the solar face we usually see — prevents us from observing the corona. Consequently, when the Moon blocks the photosphere, the corona becomes observable, and we have a chance to gather as much data as possible before the eclipse ends.

The results will hopefully help us understand solar winds and coronal mass ejections, which are massive eruptions of highly energetic plasma. If we could anticipate when they occur, we could prepare ourselves for when they strike the Earth's magnetic field.

© Getty; NASA, SDO, ESA, SOHO, Jay Pasachoff, Ron Dantowitz, Christian Lockwood and the Williams College Eclipse Expedition, NSF, National Geographic

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The RS-25 engine

How this fantastic piece of machinery will launch NASA's huge new rocket into space

If you have ever witnessed a Space Shuttle launch you'll immediately be familiar with the RS-25 engine. On the Shuttle orbiter, three of these sleek black engines would kick into life, helping the vehicle reach orbit, and NASA is now bringing this famous engine back to power its huge new rocket, the Space Launch System (SLS).

The huge thrust rating of the RS-25 makes it a powerhouse in the launch industry (NASA refers to it as the 'Clark Kent' of rocket engines). On the Shuttle each engine rated at 223,000 kilograms of thrust, but on the SLS that will be increased to 232,000 kilograms, which means that one engine could power almost 850,000 residential street lights, enough energy to go to the Moon and back more than 15 times. Turbopumps inside the engines rotate at 580 times per second, which is about twice as fast as a Formula 1 car's engine.

The engines on the SLS — which is expected to launch for the first time by 2019 — will be fed a mixture of liquid hydrogen and liquid oxygen. Together, four of the engines will help the 98-metre-tall rocket reach orbit before being discarded en route to space along with the rocket's cryogenic core fuel tank.

Over the last few years NASA has been busy testing the engines, performing several 'hot fire' tests where they were switched on while strapped to the ground. Developed by Aerojet Rocketdyne, the RS-25 engine will form a core component of NASA's plans to send astronauts back to the Moon and ultimately Mars.

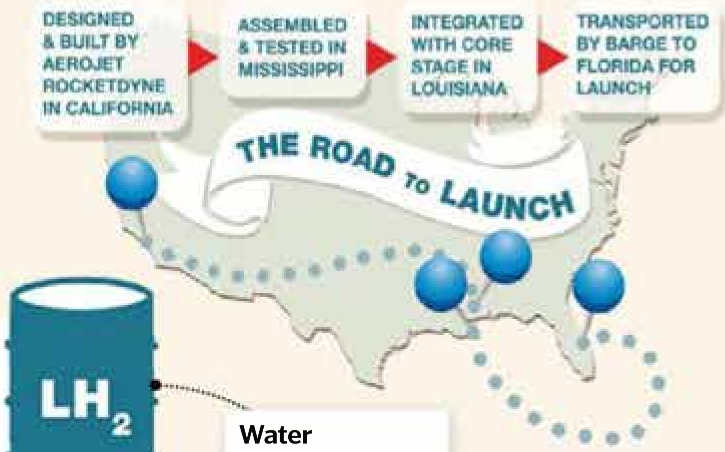
"NASA refers to it as the 'Clark Kent' of rocket engines"

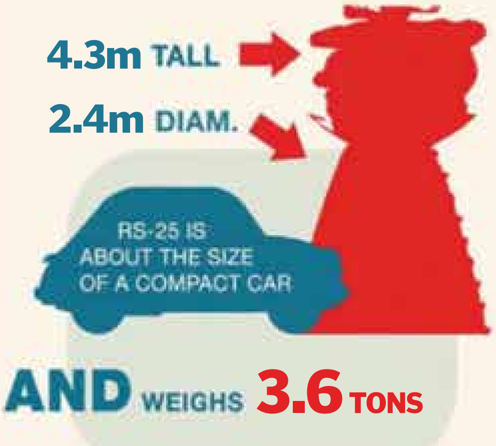
Three RS-25 engines can be seen here on the Space Shuttle Atlantis

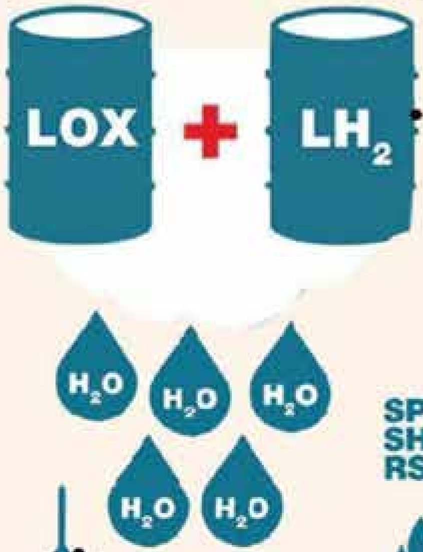
DID YOU KNOW? *Hot gas exits the RS-25 engine at 13 times the speed of sound, which could get you from LA to NYC in 15 minutes*

Inside the RS-25

What makes this rocket engine so impressive?


DESIGNED & BUILT BY AEROJET ROCKETDYNE IN CALIFORNIA
ASSEMBLED & TESTED IN MISSISSIPPI
INTEGRATED WITH CORE STAGE IN LOUISIANA
TRANSPORTED BY BARGE TO FLORIDA FOR LAUNCH
THE ROAD TO LAUNCH

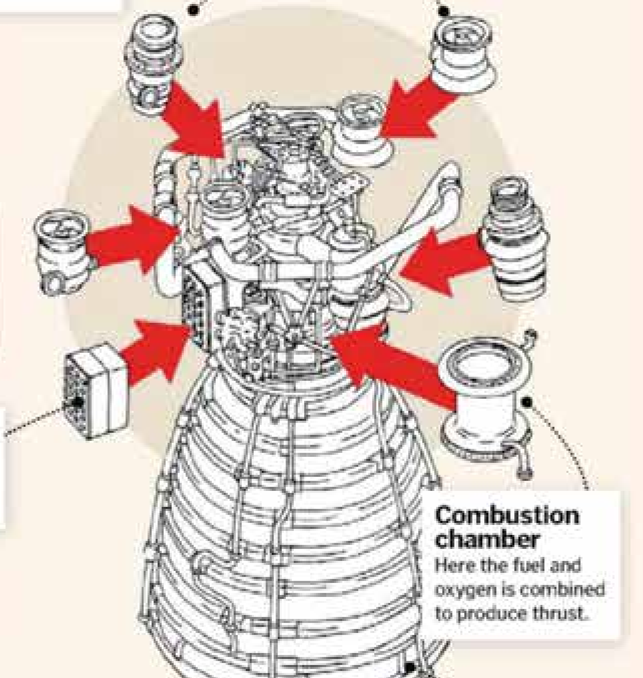

4.3m TALL
2.4m DIAM.
RS-25 IS ABOUT THE SIZE OF A COMPACT CAR
AND WEIGHS 3.6 TONS



Water
The only exhaust fumes from the RS-25 will be water vapour, not smoke, which means it burns clean.

Power
On the SLS, the engines will operate at 109 per cent power.

Turbo pumps
Four turbo pumps control the flow of liquid hydrogen and liquid oxygen inside the engine.

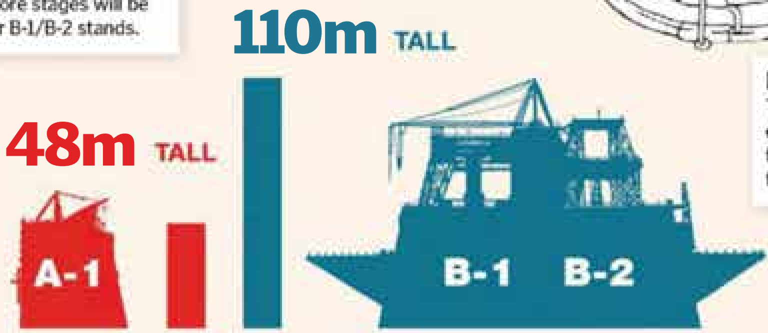


Thrust
The four RS-25 engines give the SLS about a quarter of its total thrust, alongside two solid rocket boosters.

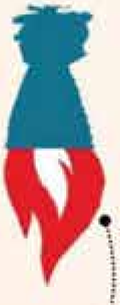
Temperature
The engine can operate from -253 to +3,300 degrees Celsius.

Combustion chamber
Here the fuel and oxygen is combined to produce thrust.

Testing platforms
Individual RS-25 engines will be tested on the A-1 stand at the Stennis Space Center. The SLS's core stages will be tested on the larger B-1/B-2 stands.



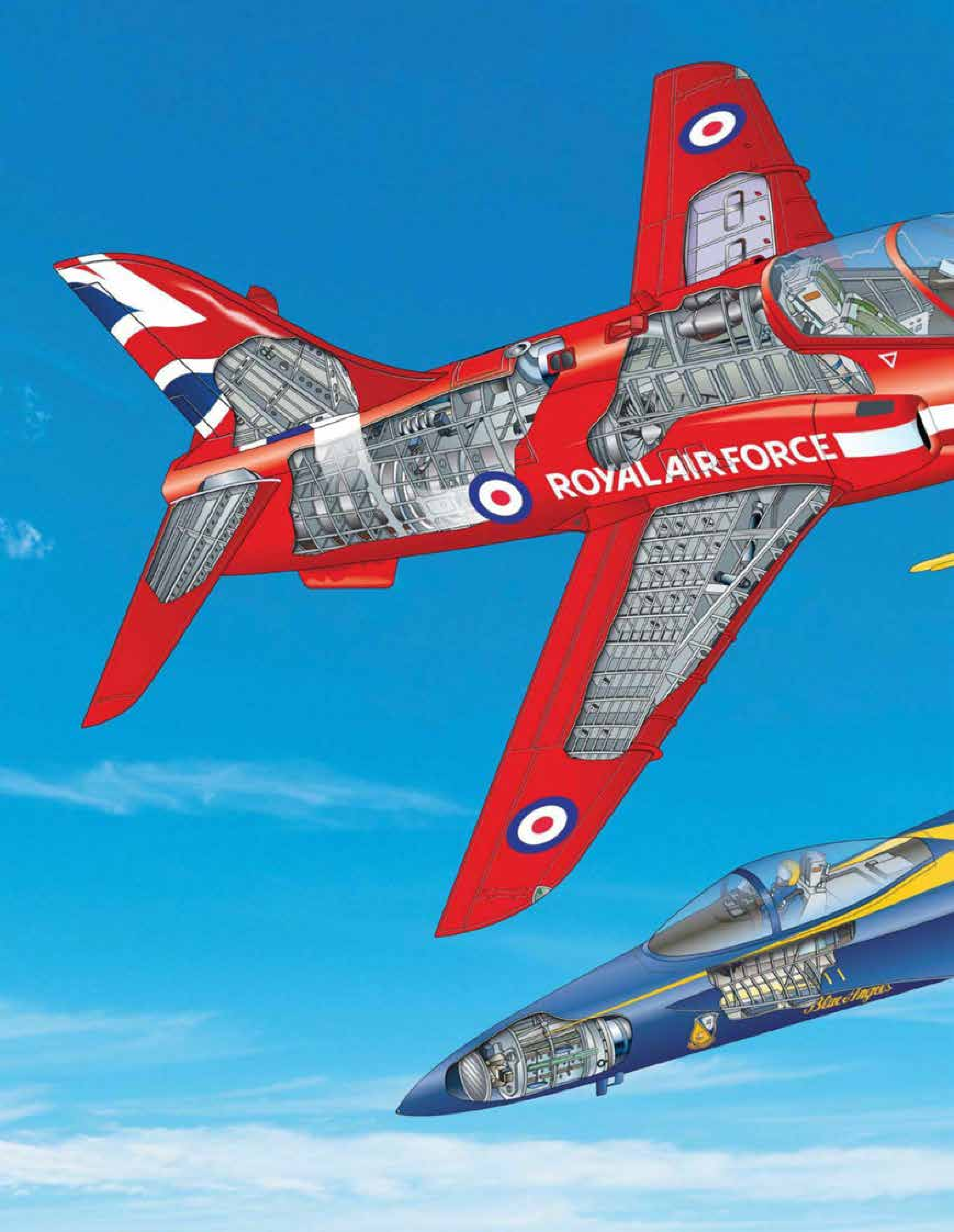
Nozzle
This fires out the resultant exhaust, directing the flow and controlling the velocity.



8.5 minutes
The amount of time the RS-25 engines will fire for on an SLS launch.

Testing
Although the engines were used on the Shuttle, they are being tested again at NASA's Stennis Space Center in Mississippi, US.

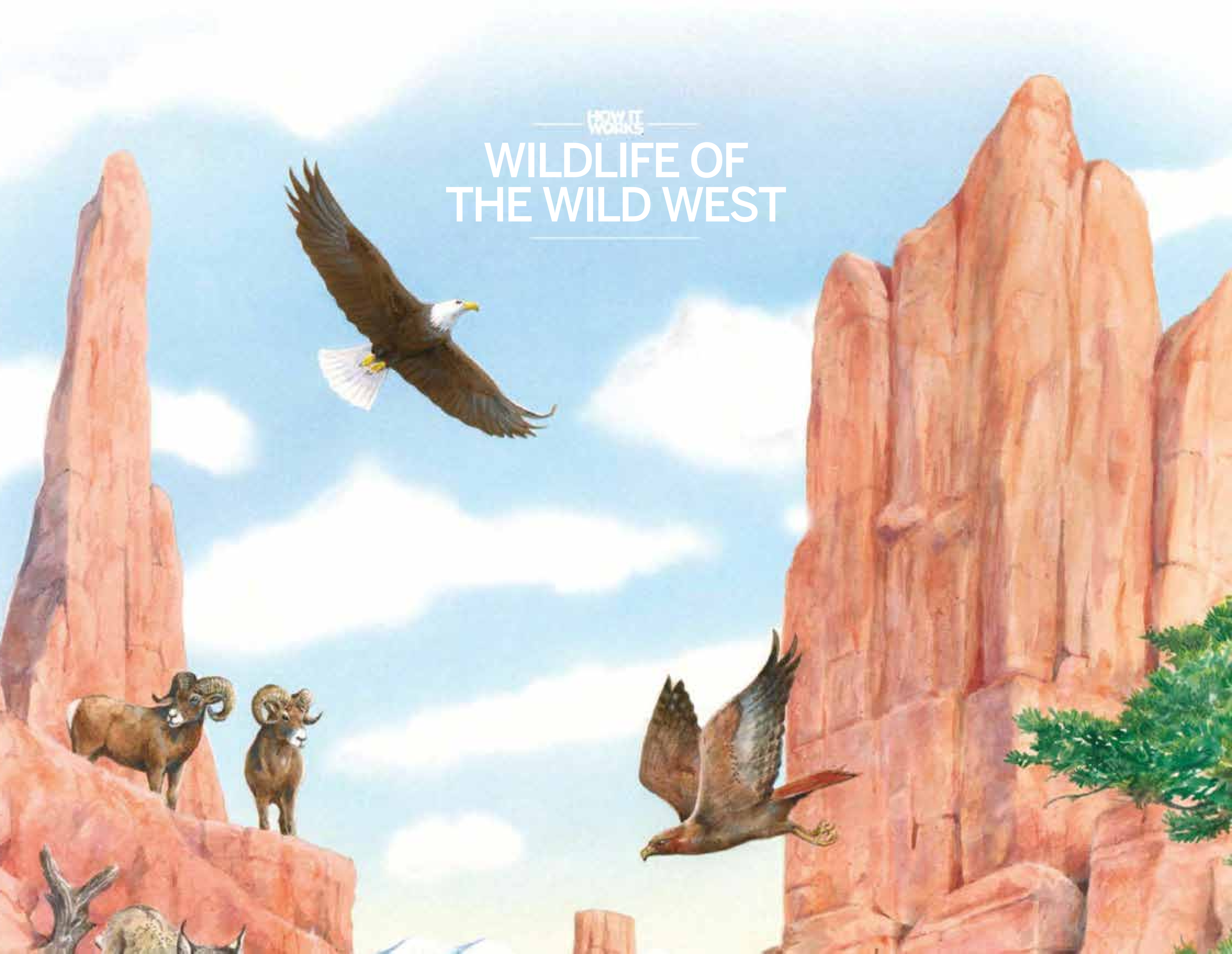
© Alamy; NASA


ROYAL AIR FORCE
Blue Angels

HOW IT WORKS

RED ARROWS AND BLUE ANGELS

WILDLIFE OF THE WILD WEST



ROSETTA SPACECRAFT

THE ULTIMATE SMART HOME

DISCOVER THE CONNECTED TECH THAT WILL MAKE OUR HOMES HEALTHIER, SAFER AND GREENER

For many of us, the term 'smart home' brings up images of robot butlers, *The Jetsons* or the high-tech interface's found built into the Stark mansion in the *Iron Man* movies. But home automation is no longer science fiction. Technology that's designed for our homes is simple to use, looks good and can make our lives easier, safer and even healthier. And don't worry, there isn't a clunky robot butler in sight.

WHAT MAKES A HOME 'SMART'?

The term 'smart home' is used to describe a house that contains technology that connects to the internet — it's as simple as that. If devices are connected to the internet this means they can connect to each other and be automated, monitored and controlled from your smartphone, whether you're home or not.

So you could ask your voice-controlled Amazon Echo to turn on your Nest thermostat and heat up your house if you're feeling cold. Or you could get out your smartphone and fire up your Arlo Q Security Camera app on your way home to show you a live-feed of your kitchen.

With a smart home you're asking your devices to communicate, send information back and forth and take your commands. For this to work you need devices that can connect to the internet. Nowadays, a lot of devices already have smart technology built-in. But many older

DID YOU KNOW? *In 1950, Ray Bradbury wrote There Will Come Soft Rains, the first sci-fi story about an automated smart home*

The tiles that make up the Tesla Solar Roof come with a warranty that covers them 'to infinity'

devices aren't smart, so you'll need to buy add-ons, like smart plugs, which enable them to connect with a little help.

SMART HOME OVERLOAD

Over the past ten years technology companies have been investing a lot of money into smart home technology. This means there's a lot of connected tech on the market, from TVs and thermostats to toothbrushes and hairdryers. But with so much smart tech to choose from, creating your own smart home can be daunting, not to mention pricey.

That's why rather than make everything smart, you can decide what's a priority for you. Because let's face it, one person might love their smart toaster and another might find it completely useless.

Right now some of the biggest trends in smart home tech are focused on health, security and being more eco-friendly. Which one will you choose to focus on?

BETTER HEALTH STARTS AT HOME

Advances in sensors that tell us more about, well, us, mean that people can take their health and wellbeing into their own hands more than ever before. And although you might associate health tech with activity trackers or specialist medical devices, there's potential for it to become a staple in your new smart home, too.

The first smart product that might one day become just as important as your kettle is a sleep tracker. Many of us know that the amount of shut-eye we get has a direct impact on our health and wellbeing, which is why many of the fitness tech companies, like Fitbit, are channelling their efforts into advanced sleep-sensing tech.

A number of sleep sensors that sit on your bed or are incorporated into your bedding already exist, like the Zeeq Smart Pillow or Beddit sensor. But having tech tucked up in bed with you, no matter how small, isn't ideal. That's why there's now a move to keep tech smarts that live on your bed to a minimum, with devices such as the S+ Sleep Monitor from Resmed analysing your body movements as you sleep instead.

Sleep tech becomes even more useful when it doesn't just track your sleep but improves it. That's why wake-up lights from Lumie and Sleepace are already popular, creating the optimal sound and lighting experience to lull you into dreamland.

However, it's not just sleep that your smart home wants to monitor but the environment, too. The Netatmo Healthy Home Coach can keep tabs on humidity, temperature, air quality and noise, then recommend how you can create a more optimal environment in which to live.

As air pollution reaches an all-time high, environment-sensing tech is becoming more important than ever, but it can also have specific applications, like if one of your family has asthma or allergies.

Sure, weighing scales aren't new, but now your old scales with a dial that would give you unpredictable results are a thing of the past. Smart scales, like the latest device from QardioBase, can now track body fat, water, BMI, muscle mass, bone composition, and in some cases even pregnancy.

As you'd expect, all of this data can then be sent to your smartphone and sync up with other apps to paint a more holistic picture of your overall health.

But our smart homes don't need to do all the tracking and sensing to make us healthier. Systems that use the data we already have from wearables like Fitbit and Misfit to make changes in the smart home could be life-changing.

Let's imagine your Fitbit senses your heart rate is high so it adjusts the lights and sounds in your home accordingly in an attempt to de-stress you. While smart homes don't work as seamlessly as that right now, they are not that far away from doing so.

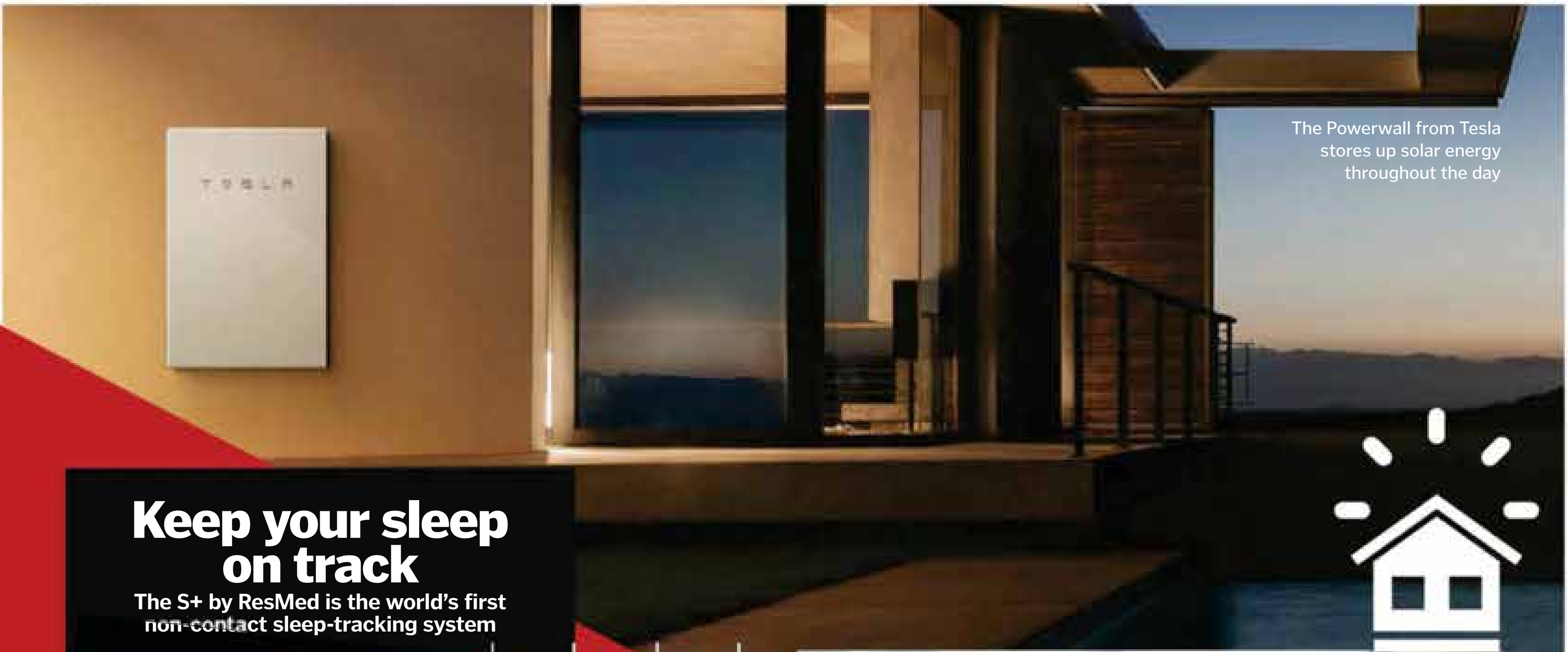
No more rummaging for keys; the August Smart Lock lets you control your door with your smartphone

Control your home with your voice with the help of Google Assistant

The Netatmo Healthy Home Coach can monitor humidity, air quality, noise and temperature

© Tesla; Netatmo; August; © Google

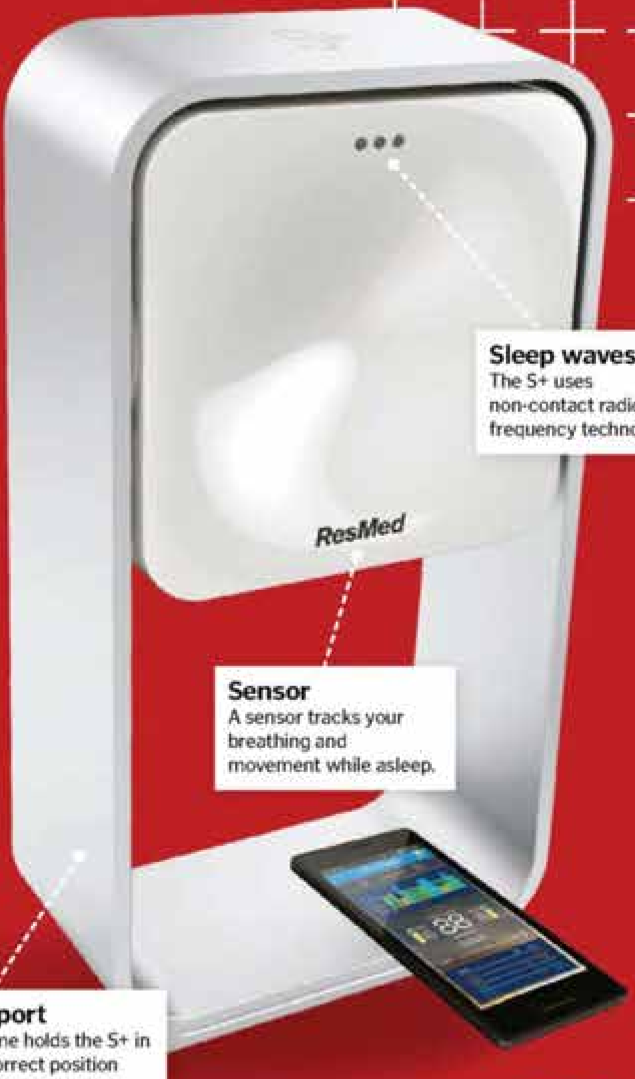
> "Some of the biggest trends in smart home tech are focused on health, security and being more eco-friendly"



The Powerwall from Tesla stores up solar energy throughout the day

Keep your sleep on track

The S+ by ResMed is the world's first non-contact sleep-tracking system



Sleep waves
The S+ uses non-contact radio frequency technology.

Sensor
A sensor tracks your breathing and movement while asleep.

Support
A frame holds the S+ in the correct position above your matress.

Our tablets and smartphones become control panels to operate our smart homes

The Amazon Echo allows you to control your smart home with your voice

The smart home tech that ends up succeeding in the wellness and health space will be the tech that does something about our problems rather than just sensing them.

For example, being notified that the air is of a poor quality today is one thing. But turning on your air purifier, opening windows and making tweaks to the home with the help of other devices is when it'll become useful and invaluable in the not-so-distant future.

SAY GOODBYE TO YOUR GUARD DOG

One of the main reasons people want to invest in smart home technology is because they want to feel safer in their homes. Up until now, making your home secure has been an expensive, time-consuming and not always effective task. But thanks to the influx of smart home technology that has security at its core, you have more opportunity than ever to monitor what's going on at your house at all times.

One of the biggest developments in smart home tech is in security cameras. Luckily, there's a huge range of products available, from small and simple cameras that give you peace of mind through to surveillance systems monitored by private companies.

The Nest IQ Cam is a mid-range camera that can see in the dark and has a digital sensor to alert you to intruders and stream footage straight to your phone. Then at the other end of the scale there's the LG Smart Security Wireless Camera, which has an indoor security camera that provides 24/7 monitoring via security company ADT's Canopy service.

If constant surveillance seems like overkill to you, then maybe a smart lock is what you need instead. Traditional lock companies like Yale have been working on smart devices that allow you to access your home with only your smartphone.

If you're making your front door smart, you may as well make every other entry point smart, too. The Hive window or door sensor can be added to, you guessed it, any window and door so you'll then be alerted via the app if one opens while you're out.

But it's not just threats from people getting in that might be the issue. The Nest Protect is a smoke and carbon monoxide alarm that alerts your phone as well as sounds an alarm if it detects either. It also works in tandem with other Nest products. So if the Nest Protect detects smoke, the Nest Learning Thermostat will turn the boiler and radiators off.

The future looks bright for smart home security, giving people peace of mind from their fingertips. But as these types of devices become more widespread, technology brands will need to be wary of their own security so consumers feel safer and not concerned about leaked data or hacks.

SAVING THE PLANET AS WELL AS YOUR PENNIES

We all know that cutting down on our consumption, increasing our recycling and turning to renewable energy sources is a group effort and everyone needs to play their part. Thankfully, smart tech is here to make it easier for us all to be kinder to the planet.

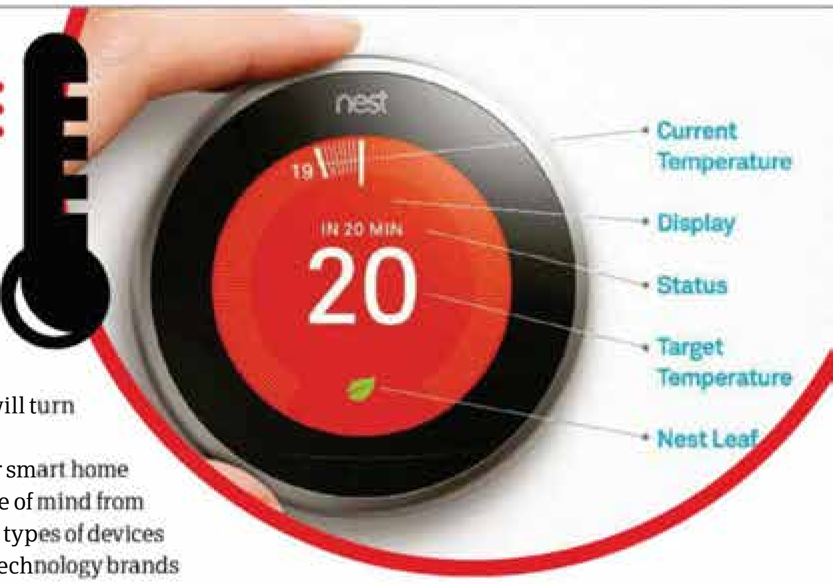
It may seem counterintuitive that we're creating new technology in order to stop us wasting so much and using too much energy. But clean energy is a rapidly growing industry and there's a lot of tech on the market at the moment that could turn even the most reluctant recycler into an eco-warrior.

The most obvious, cheap and easy way to make your home greener is to reduce your consumption, and luckily lots of smart home products enable you to do that easily.

Thermostats like the Nest Learning Thermostat talk to your boiler and can control water heating and radiators, allowing you to monitor everything from your smart phone so you can figure out where you can make changes.

To keep an eye on water consumption, a device such as Flo works like Nest but for your water, learning your habits over time and providing you with insights about how much you use and when. Similarly, Hydrao is a smart shower that uses LED lights to show you how much water you're using, turning saving water into a fun game.

> "Thanks to the influx of security technology, you can monitor what's going on in your house at all times"



The Nest Learning Thermostat learns your preferences and adjusts your heating to suit

These options might seem dull, but they're the easiest and most financially viable ways for most people to do their bit. Well, unless you have enough spare cash to clad your home in advanced solar panels.

The Solar Roof from Tesla consists of solar panels that turn sunlight on your house into electricity, which can then be stored in the company's Powerwall. Of course, solar panels have existed for a while. But what sets this new breed of solar tech apart is that the tiles used to build the roof look like regular roof tiles, they're more durable, despite being constructed from glass, and they have made headlines for coming with a warranty covering them for 'infinity'.

TEACHING THE SMART HOME HOW TO BE SMARTER

The most popular smart home products at the moment are virtual assistants like the Amazon Echo and Google Home. They're voice activated and act as hubs for your smart home, bringing everything together and allowing you to dictate what you want your smart tech to do and when.

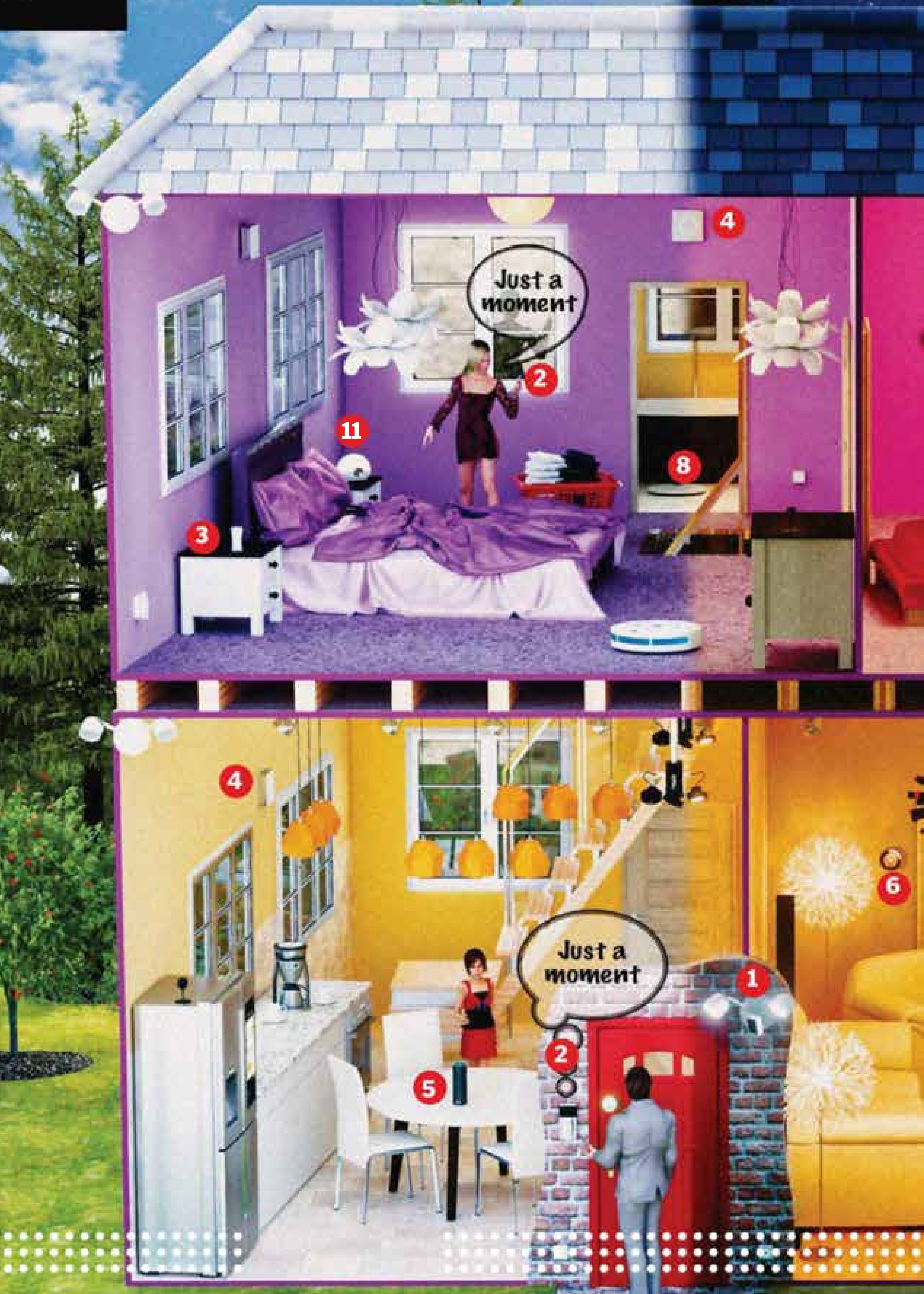
The rise in these home assistants will make smart home tech even easier to add to your daily routine because you can use your voice and access everything from one place. Think of the smart assistant like the boss that tells all the other tech what to do.

Where there's even greater opportunity is for these smart hubs to learn more about you. The more it knows, the more it can help and begin to automate things all on its own, like putting the lights on when you're on your way home, alerting you to poor air quality and making adjustments or making your lights warmer on a night to promote healthier sleep patterns. That's when the smart home will get even smarter.

© Tesla; Getty; Amazon; Nest; Resmed

Welcome to your future smart home

Step inside the house that knows you better than you know yourself



1 Upgrade your guard dog
Security cameras can keep an eye on your home 24/7, alerting you if there's movement and flooding the area with light to deter intruders.

2 Smart doorbell
A video doorbell allows you to see, hear and even speak to anyone at your door, even if you are not at home.

3 Air sensing
If you have allergies or asthma, the Cair Smart Air Quality Sensor can alert you as soon as issues arise.

4 Upgrade the smoke alarm
The Nest Protect is a smart smoke and carbon monoxide alarm that also doubles up as a night light.

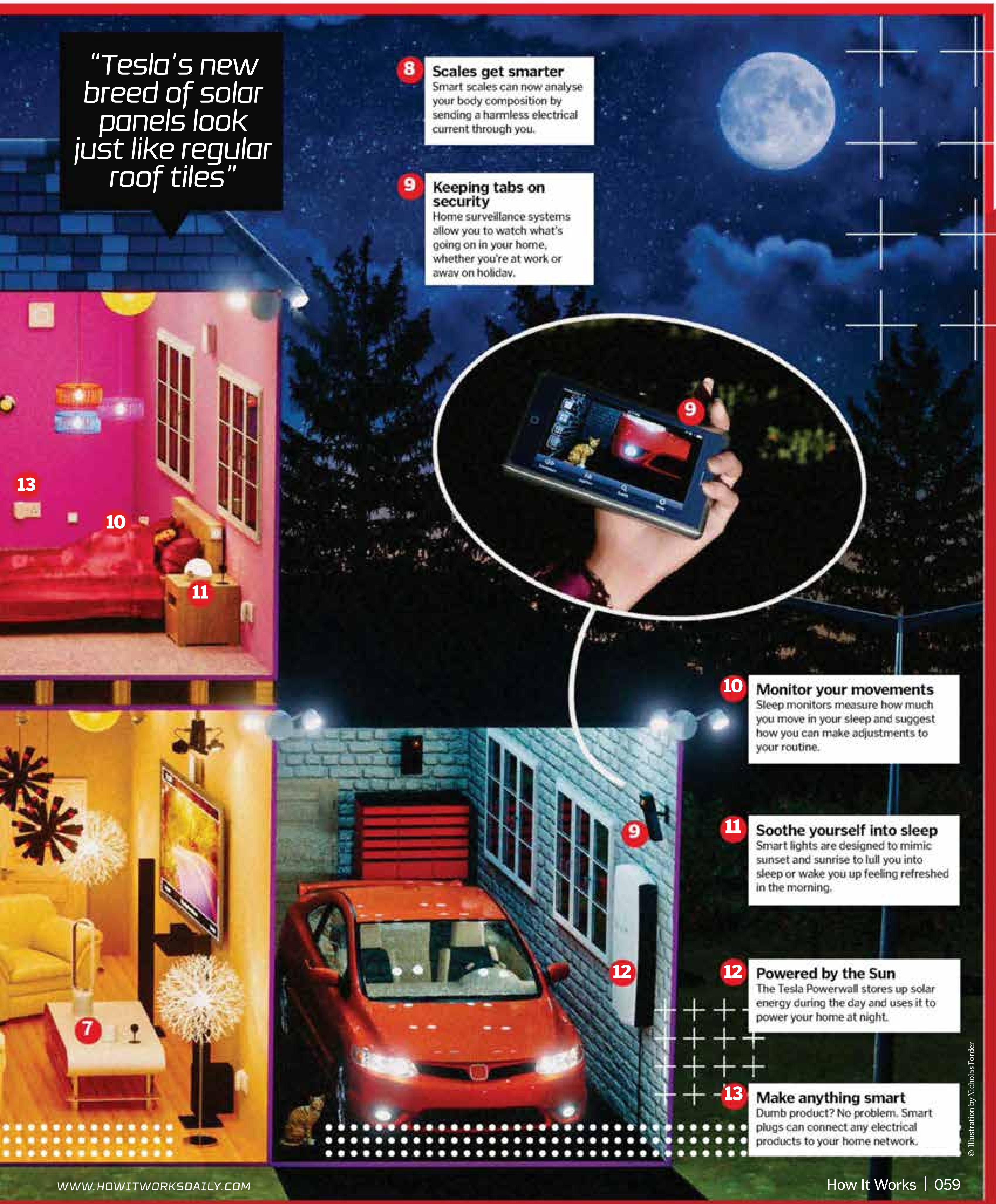
5 Say hello to Alexa
Smart voice assistants act like the boss of your home, bringing all your connected products together.

6 Room temperature
Devices like the Nest thermostat learn your schedule, so they can make sure the heating is on when you need it, and turn it off when you don't.

7 Cleaner air
The Dyson Pure Cool Link promises to get rid of gas, allergens and pollution from the air in your home.

DID YOU KNOW? *Amazon is thought to have sold more than 10 million Alexa-powered Echo smart devices since 2014*

> “Tesla’s new breed of solar panels look just like regular roof tiles”



8 **Scales get smarter**
Smart scales can now analyse your body composition by sending a harmless electrical current through you.

9 **Keeping tabs on security**
Home surveillance systems allow you to watch what’s going on in your home, whether you’re at work or away on holiday.

10 **Monitor your movements**
Sleep monitors measure how much you move in your sleep and suggest how you can make adjustments to your routine.

11 **Soothe yourself into sleep**
Smart lights are designed to mimic sunset and sunrise to lull you into sleep or wake you up feeling refreshed in the morning.

12 **Powered by the Sun**
The Tesla Powerwall stores up solar energy during the day and uses it to power your home at night.

13 **Make anything smart**
Dumb product? No problem. Smart plugs can connect any electrical products to your home network.

© Illustration by Nicholas Forder

The latest version comes with a recipe app and digital recipe chips

Thermomix looks like a regular blender, but it can simmer, steam and weigh

Thermomix explained

Meet the kitchen gadget that cooks, whisks, weighs, chops, steams, stirs and cleans

Vorwerk wanted to combine as many kitchen features as possible into one machine, so they invented the Thermomix. It's got a jug with a temperature sensor, a base that heats up to between 37 and 120 degrees Celsius, and a set of blades that can whip round at over 10,000rpm. And it can prep thousands of meals at the turn of a dial and the touch of a screen.

Thermomix has four blades that sit at different heights and at different angles, allowing this single attachment to stir gently or mix fast, chop roughly or create a fine puree. Food can be weighed and heated as it's being prepared, and, if you need to whisk, there's an attachment that sits on the blade to whip air into the food.

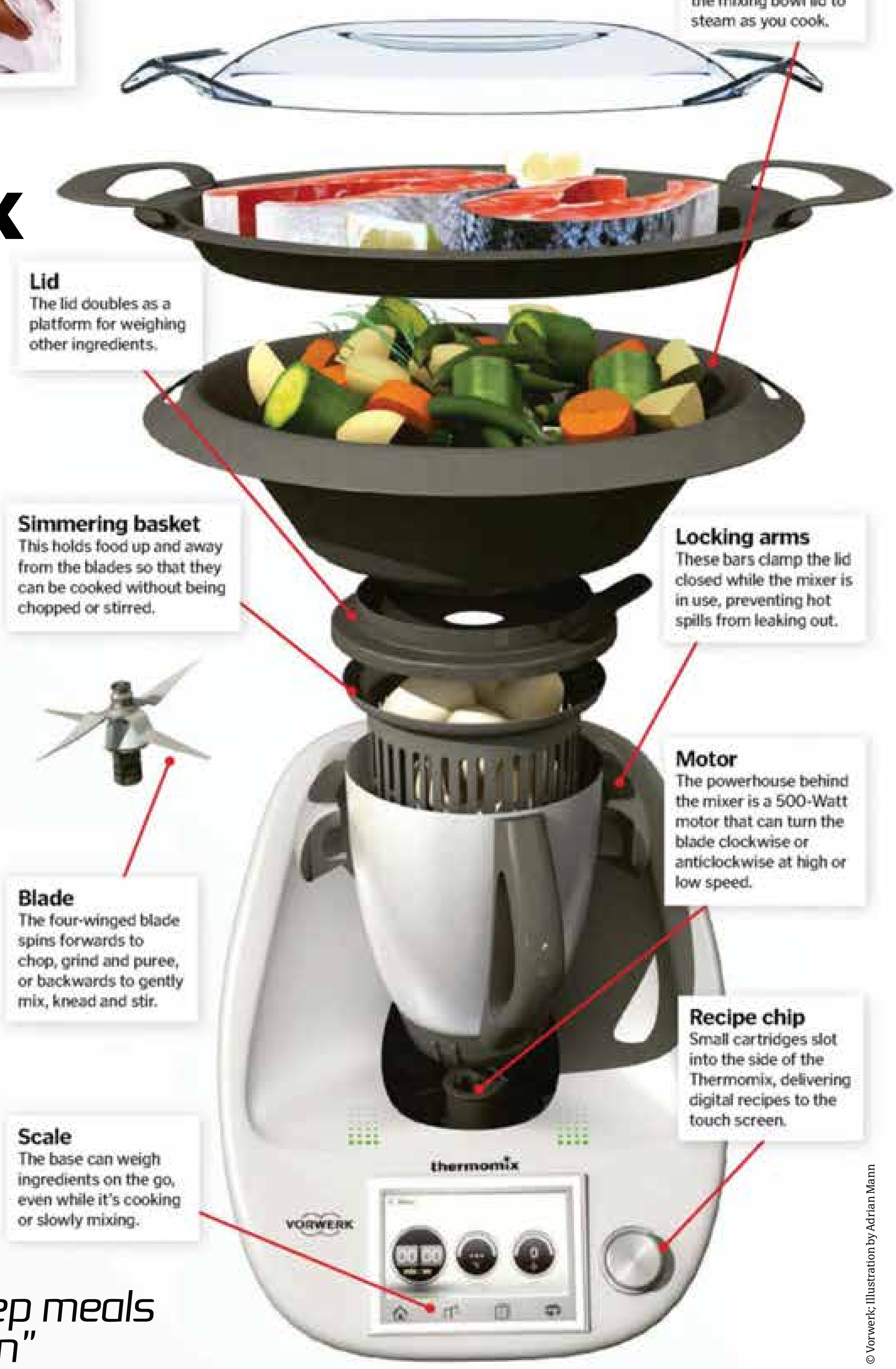
The lid can be clamped in place during use, and it's got a convenient hole with a custom measuring cup that lets steam out and liquids in. The flat top allows the weighing feature to be used independently of the mixer, and it also provides a place to gently steam vegetables, fish or rice in a specially designed basket.

And for super-simple cooking, there are digital recipe chips that clip into the side of the machine. Everything is programmed in, from the temperature to the timings, and it's got a 'guided cooking' feature that combines several cooking steps into one. Just add the ingredients and press play.

> *"The Thermomix can prep meals at the touch of a screen"*

Inside the Thermomix

The mixer is equipped with custom gadgets to perform different kitchen tasks



Varoma
A specially designed steamer sits on top of the mixing bowl lid to steam as you cook.

Lid
The lid doubles as a platform for weighing other ingredients.

Simmering basket
This holds food up and away from the blades so that they can be cooked without being chopped or stirred.

Locking arms
These bars clamp the lid closed while the mixer is in use, preventing hot spills from leaking out.

Motor
The powerhouse behind the mixer is a 500-Watt motor that can turn the blade clockwise or anticlockwise at high or low speed.

Blade
The four-winged blade spins forwards to chop, grind and puree, or backwards to gently mix, knead and stir.

Recipe chip
Small cartridges slot into the side of the Thermomix, delivering digital recipes to the touch screen.

Scale
The base can weigh ingredients on the go, even while it's cooking or slowly mixing.

© Vorwerk; Illustration by Adrian Mann

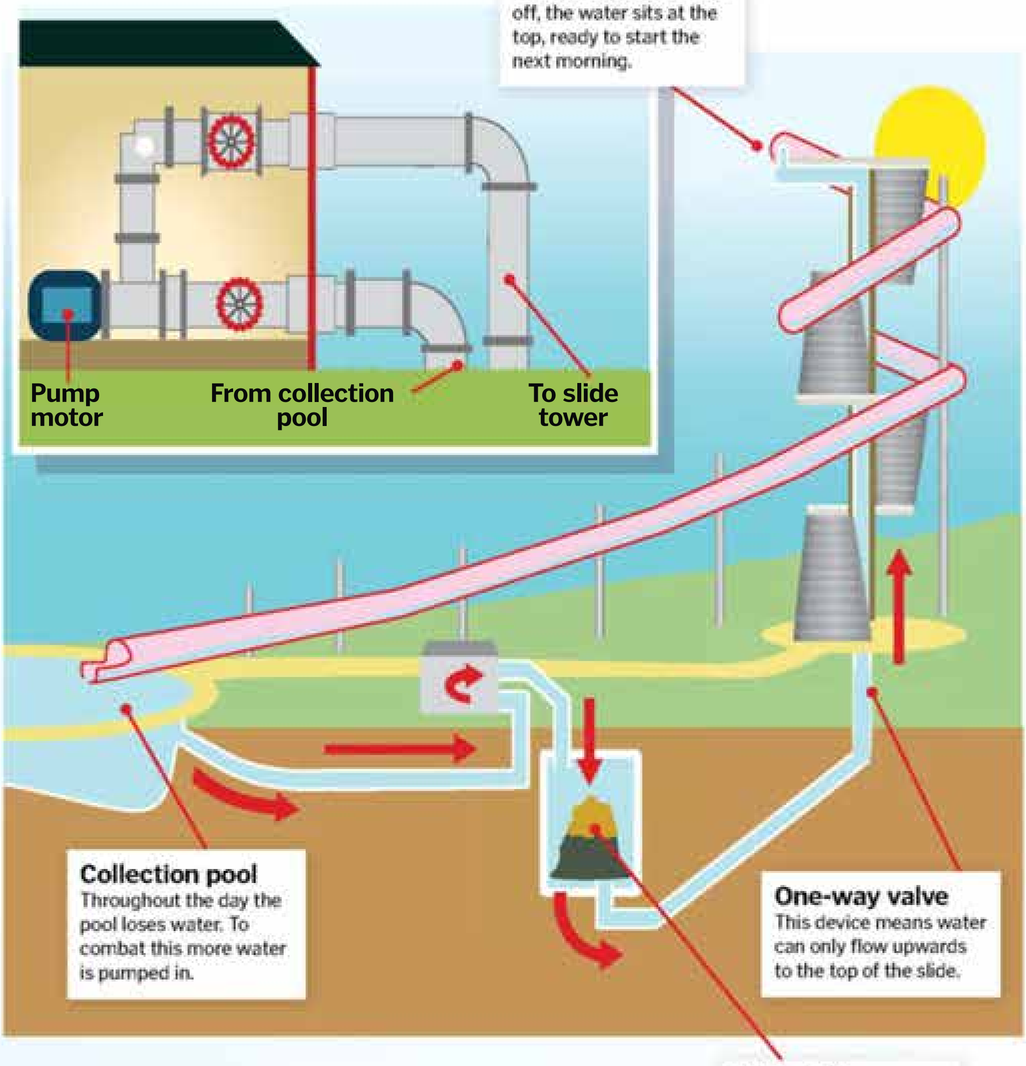
DID YOU KNOW? *The world's tallest water slide is the Kilimanjaro at the Aldeia das Águas Park Resort in Barra do Piraí, Brazil*

Water slides

We look at the physics and engineering behind these waterpark attractions

A fun fixture of amusement and holiday parks, a lot of work goes into keeping water slides safe and reliable for visitors. Key to the slide working is keeping water flowing in order to reduce friction for the rider on the way down. Essentially, a pump near the bottom of the slide turns a drive shaft attached to a propeller, drawing water from a collection sump and pushing it through a pipe to the top, in the process ensuring a constantly recycled supply of water. Sometimes this will go through a further series of pools to clean it out before it is channelled back to the top of the slide.

The use of waterslides dates back to at least 1906



Quick start
When the valve is turned off, the water sits at the top, ready to start the next morning.

Collection pool
Throughout the day the pool loses water. To combat this more water is pumped in.

One-way valve
This device means water can only flow upwards to the top of the slide.

Water filter
This is filled with sand and gravel, which traps excess dirt as the water passes through.

> *"A lot of work goes in to keeping water slides safe and reliable"*

Making waves

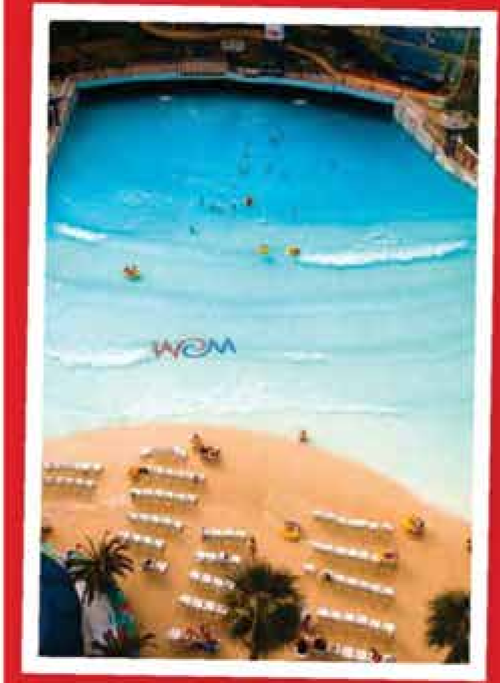
The tech that makes swimming pools come to life

Wave machines are a lot of fun, livening up otherwise staid swimming pools, and in many ways they appear to be a modern marvel.

In truth, however, the method to the machinery is pretty straightforward. The mechanisms that cause the waves are contained in a pump room situated out of sight next to or below the swimming pool. Here, a high-speed fan or air pump funnels air through an exhaust port and out into an air chamber.

Once in the chamber, a disc on a metal axis rocks back and forth at regular intervals, allowing the flow of air into the swimming pool. When this happens, the arrival of air produces waves. The longer this goes on for, the stronger they get.

In larger pools this works slightly differently. Instead of just air, larger volumes of water are added to the deep end of the pool, in the process creating larger waves — the more water that's added, the bigger the size of the waves. The result is a surge as the water level balances out.



Excess water is channelled through a canal that returns the water to its source, allowing more waves to be generated

© Alamy; Thinkstock; Illustration by Neo Phoenix

Golf ball tech

Professional balls are specially engineered to maximise your game

At their simplest, golf balls are made from a single layer of scratch-resistant resin. These basic balls are hard wearing and fly long distances through the air, but most balls have more than one layer.

Two-piece balls have a hard plastic core for extra distance, and three-piece balls contain a rubber core coated with wraps of rubber banding. The outer layer can also be changed, swapping the tough coating for softer materials like urethane. These balls don't go quite as far, but they can take more spin on short shots, giving professionals much more control.

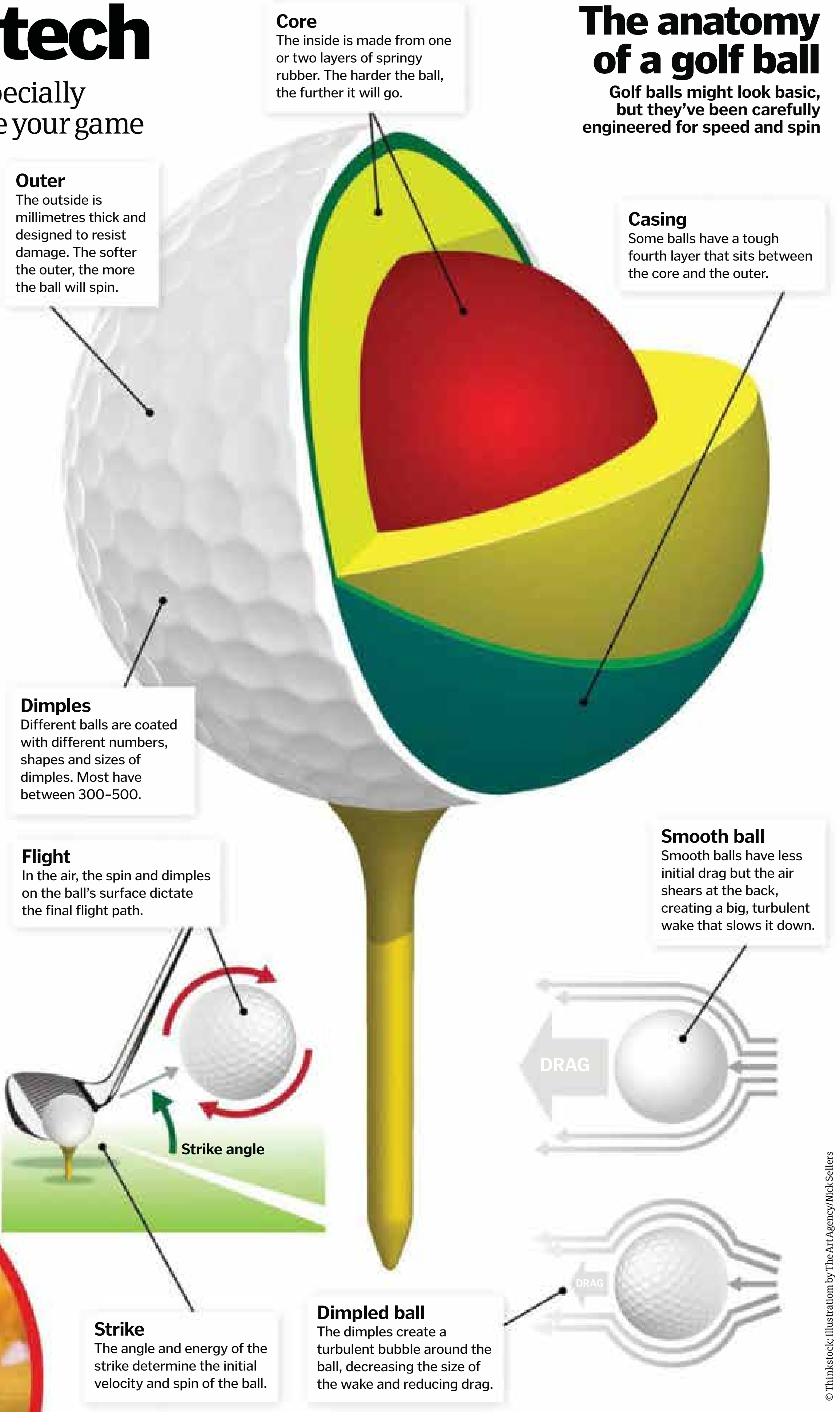
But there's one key feature that makes golf balls stand out; their dimples. The game was originally played with smooth balls, but players noticed that older balls went further. These battered balls were covered in scratches and dents, and the change to the surface altered the air flow.

Air wraps around the curve of a ball as it flies through the air, and some molecules stick to the surface creating a 'boundary layer'. But the air behind smooth balls detaches from the surface and sticks to the fast-moving air rushing past. This detached airflow in the wake of the ball creates drag.

By coating the ball in dimples, the airflow becomes turbulent. This increases the initial drag but creates a thicker boundary layer that helps the air to cling to the ball at the back, thereby decreasing the size of the wake and helping to generate even more lift. Subtle changes to the dimples tweak the exact dynamics of each ball design.

The anatomy of a golf ball

Golf balls might look basic, but they've been carefully engineered for speed and spin



Core
The inside is made from one or two layers of springy rubber. The harder the ball, the further it will go.

Outer
The outside is millimetres thick and designed to resist damage. The softer the outer, the more the ball will spin.

Casing
Some balls have a tough fourth layer that sits between the core and the outer.

Dimples
Different balls are coated with different numbers, shapes and sizes of dimples. Most have between 300–500.

Flight
In the air, the spin and dimples on the ball's surface dictate the final flight path.

Smooth ball
Smooth balls have less initial drag but the air shears at the back, creating a big, turbulent wake that slows it down.

Strike
The angle and energy of the strike determine the initial velocity and spin of the ball.

Dimpled ball
The dimples create a turbulent bubble around the ball, decreasing the size of the wake and reducing drag.

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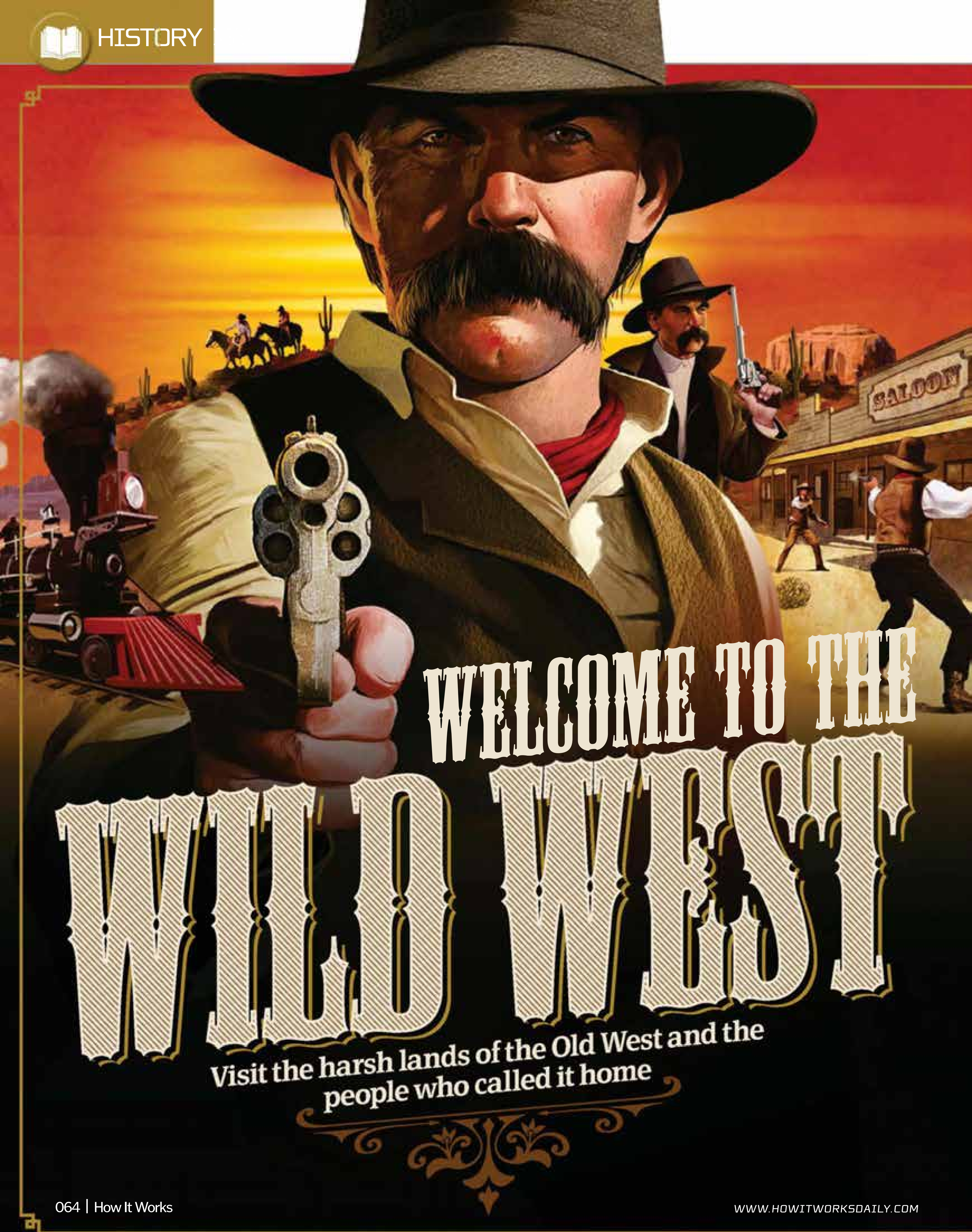


WELCOME TO THE WILD WEST

Visit the harsh lands of the Old West and the people who called it home

DID YOU KNOW? *Even though hats were popular, settlers in the Old West rarely wore the classic 'cowboy hat'*

The discovery of precious metals attracted large numbers of miners to the west

When we picture the Wild West, we immediately think of a scorched desert where cowboys, sheriffs and bandits shelter from the Sun in saloons with swinging doors. There they sit drinking whisky and eyeing each other suspiciously, their twitching fingers hovering by the revolver pistol strapped to their waist, all ready for a mass gunfight at a moment's notice.

So how accurate is this Hollywood depiction of the Old West? And how did this fascinating period of history arise? In this feature, we're going to step into a pair of spurred riding boots and head into the sandy towns of western America during the mid-19th century. But first we'll explore how the first settlers arrived there.

By 1790 the United States of America had been born. The former 13 British colonies on the east coast had unified, and the colonists soon turned their attention westward towards the rest of the unexplored North American continent. These settlers had paid a bloody price for their independence from Britain, and in their pursuit of new conquest, territory and ownership would find much more violence in the years to come.

Fast forward to the 1840s and the colonists had successfully navigated their way from territory to territory and arrived on the western coast. They had ousted the Native American and Mexican inhabitants and begun to make themselves at home. They were then followed by a surge of new settlers in 1848 when gold was discovered in the Californian region. The influx of people quickly outpaced the sophistication of the towns that housed them, and the new settlements quickly became unruly places. The era of the Wild West had begun.

Movies and literature are saturated with stories of gunslingers — pistol-wielding 'cowboys' who blew bandits away with their quick-draw techniques, but most inhabitants of the West were at first miners and farmers. The government even gave away land for free to settlers who opted to migrate west, permitted they remained for several years. But some inevitably fell on hard times — in part due to the unforgiving soil — and opted to embrace the life of an outlaw. Criminal numbers grew in the following years when the American Civil War ended and guerrilla fighters on the losing side sought plunder instead of farmland.

The turbulent new country of the US became host to a western frontier that was dominated by quests of expansion and conquest but was famed for robberies and banditry, gunslingers and law enforcers. It was an exceptional time, and within these pages we can learn more about this fascinating period. Are you ready, gunslinger?

> "THE TURBULENT WESTERN FRONTIER BECAME FAMED FOR ROBBERIES AND BANDITRY"

WILDWEST MYTHS BUSTED

Everyone was an outlaw

There are probably more iconic criminals from this brief period of history than any other, but most settlers in the West were simple farmers and miners.

Cowboys were gunslingers

Although the term is often used to describe a pistol-wielding mercenary, a 'cowboy' was a farmer who herded and tended to cattle, mostly while on horseback.

Saloons were dangerous places

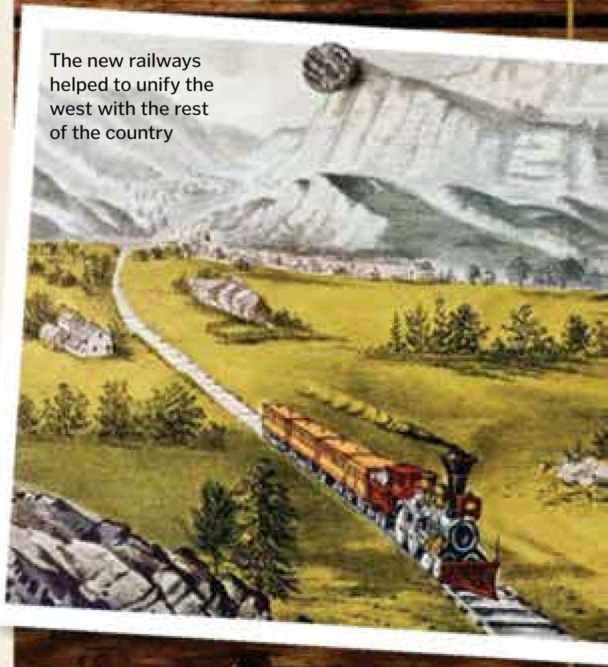
This is only part myth, as saloons were certainly fatal for many customers. But they also served as town halls on occasion, and some respected lawmen owned their own establishments.

Whiskey was the drink of choice

Although it was called whiskey, the alcohol served in saloons was more akin to a modern moonshine — it was typically a combination of raw alcohol, burnt sugar and chewing tobacco.

Guns were everywhere

The early Wild West was dangerous, but as time wore on and towns became safer, carrying a gun became unnecessary. Some settlements even banned them from being carried.



The new railways helped to unify the west with the rest of the country

LAW AND ORDER IN THE OLD WEST

How sheriffs, bounty hunters and touring judges delivered justice to the western frontier

If the Second Amendment of the US Constitution — which describes the right of the people to bear arms — teaches us anything, it's that American citizens spent a large period of their history without established law enforcement. This was especially prevalent in the Old West, where the colonists were mostly left to take the law into their own hands, and their ability to play the role of judge, jury and executioner led to a unique and dangerous form of justice.

When colonists first endured the gruelling journey to the western regions and discovered the potential treasures to be had there, the new towns and settlements soon saw their numbers swell. A town originally populated purely by prospectors and farmers swiftly became home to large numbers of new miners and traders.

The rate of crime inevitably soared with the booming population and theft, saloon brawls and gunfights all became more common. In the absence of a structured law system many territory settlements passed judgements themselves and corruption was rife. It seemed that the rule and procedure of law also had to make the slow migration to the west coast.

Eventually, the more established colonies hired sheriffs and marshals to keep the peace. These men would lock up drunkards and aggressors and track down more notorious outlaws with the help of citizens. To attract these bounty hunters the lawmen used 'Wanted' posters, which promised a handsome reward for a fugitive captured 'dead or alive'. Famous outlaws were worth huge amounts — Jesse James, for example, was worth $5,000, which was a considerable sum for the time.

If taken alive, the captured parties were sometimes placed in front of touring judges that had come from neighbouring regions to deliver justice. These officials were quite different to the judges of today, preferring to hold court in an informal fashion. Resting their feet on a desk, whittling and chewing tobacco were all acceptable behaviours for a presiding lawman. And the bizarre practices didn't end there. On the western frontier, where money was scarce, wealthy parties were often fined if convicted of a crime. And on at least one occasion the guilty party paid in warm clothing for the judge and marshal! Even more so than today, money and violence ruled in the Wild West.

Gambling, especially while playing the card game *Faro*, was popular in saloons

> "MONEY AND VIOLENCE RULED IN THE WILD WEST"

TOWN HERO

ABIGAIL SCOTT DUNIWAY

Not every hero of the Wild West was a rambunctious gunslinger, as Abigail Scott Duniway proved during her remarkable lifetime. Crossing into Oregon in 1852, Duniway was hired as a schoolteacher but later found her calling as a champion for women's rights. At the age of 78 she became the first woman to vote in her county.

TOWN HERO

WYATT EARP

The line between noble lawmen and opportunistic mercenary was a blurry one in the Old West, but Wyatt Earp is largely celebrated as a great law enforcer in a region that really needed it. Described as "absolutely destitute of physical fear", Earp excelled as a policeman, assistant city marshal and stagecoach guard during his career.

© Getty; Illustrations by Adam Markiewicz

Key dates in the history of the Wild West

1820S	Colonist 'mountain men' travel west to the Rockies for hunting.
1841	A wagon train makes the first journey to the northwest coast.
1844	1,500 settlers migrate from the eastern territories and arrive in California.
1846	The US declares war on Mexico, which claims ownership of the west.
1848	Mexico concedes and agrees to sell California and its northern territories.

DID YOU KNOW? *In the early years of the Wild West the demand for lawyers was so low that many worked in the mines!*

Heroes and Villains

Meet the exceptional characters that epitomised life in the Old West

TOWN HERO

ANNIE OAKLEY

Born under the name Phoebe Moses, the woman who became Annie Oakley gained fame as a sharpshooter through Buffalo Bill's Wild West shows. Oakley was so accurate with her rifle that she could shoot the ash off the tip of a cigarette! Native American Chief Sitting Bull gifted her a worthy nickname: 'Little Sure Shot'.

WANTED

BELLE STARR

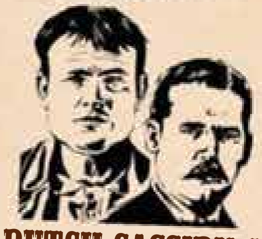
Starr gained such infamy during her lifetime that most tales of her exploits have now been distorted by fiction. After the civil war we know she allied herself with guerrilla groups who specialised in robbing banks, stagecoaches and fellow settlers. For years she planned crimes, harboured fugitives and committed robberies before meeting a grisly end.

WANTED

DOC HOLLIDAY

Before turning to a wild life, John Henry 'Doc' Holliday was a practising dentist. He decided to travel to the drier climate in the west to alleviate a chronic cough and soon found himself entangled in numerous gunfights. He later took up a life of gambling and was suspected of robbery and murder.

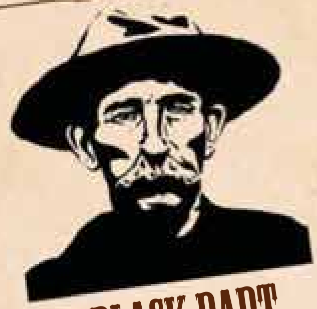
WANTED



BUTCH CASSIDY & THE SUNDANCE KID

Robert Parker (Butch Cassidy) and Harry Longabaugh (The Sundance Kid) helped to form 'The Wild Bunch', a group of former labourers who turned to crime in search of bigger profits. For years they succeeded in robbing banks and trains, retreating to the deep canyons of Wyoming and Utah to hide from the law after a heist.

WANTED



BLACK BART

Charles Boles was a California stagecoach robber who garnered a reputation for being incredibly well mannered and polite to his victims. He acquired his villainous identity from a 'dime novel' in a local newspaper in which a man with black hair, a black beard and black clothes robbed unsuspecting stagecoaches. His name was Black Bart.

WANTED

BILLY THE KID

Born Henry McCarty in New York City, Billy the Kid came to the fore on the other side of the country in New Mexico, where his notorious criminal career began. He shot and killed someone in a saloon fight and joined a faction war while still an adolescent. After committing a series of murders he was killed himself, aged just 21.

1848

Prospectors discover gold near Sacramento for the first time.

1849

40,000 gold miners arrive in the west, starting the famous California Gold Rush.

1850

Native Americans of the Sierra Nevada fight the prospectors.

1850

Home to over 60,000, California becomes the 31st US state.

LIFE IN A WILD WEST TOWN

Explore the everyday lives of settlers living in the barren Old West

Saloons

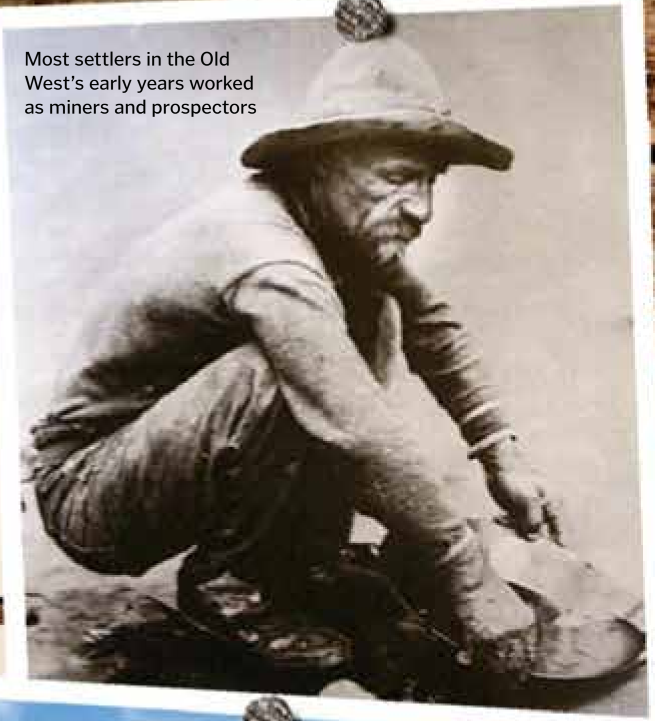
After a hard day's work, there was little settlers enjoyed more than visiting the saloon. It was home to all manner of debauchery, including dancing girls, hard liquor, gambling, and sometimes even gunfights. Early saloons were little more than tents propped up on the roadside in the hopes of luring in a weary traveller, but as towns grew they transformed into something more like the swinging-door establishments we're all familiar with.

Saloons were popular places where settlers could drink liquor, play card games and gamble

> "MOST GUNFIGHTS WERE FOUGHT BEHIND COVER BETWEEN GROUPS OF INTOXICATED MEN"

Jobs

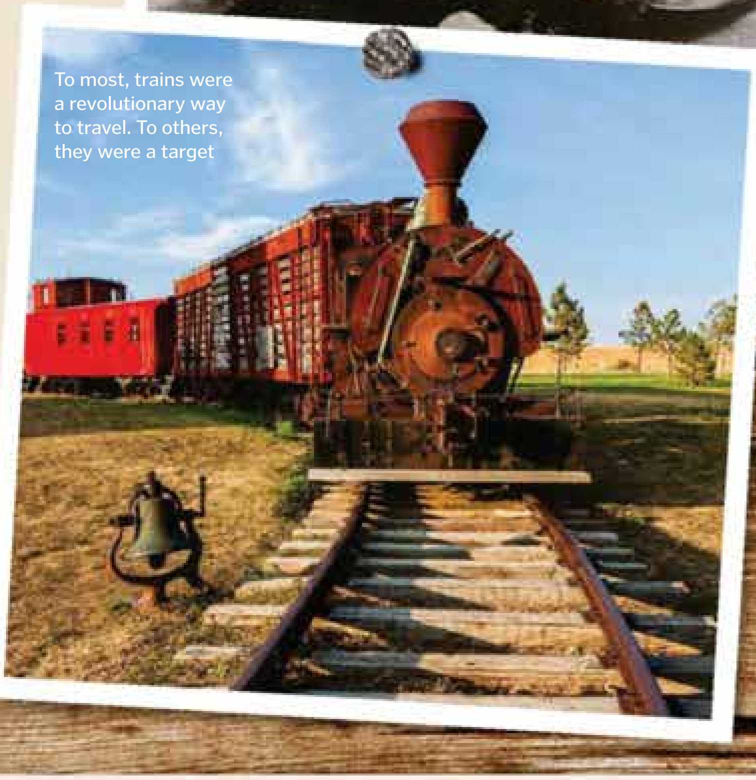
The famous California Gold Rush and other subsequent precious metal finds brought miners and prospectors to the west in their thousands. And where people go, trade follows, and soon bartenders, merchants, doctors and entertainers all arrived in the region. The government encouraged this migration and offered free farmland to new settlers, which helped develop the western economy further and paved the way for more investment and more job opportunities in the region.



Most settlers in the Old West's early years worked as miners and prospectors

Travel

The first colonists to arrive in the west did so the old-fashioned way. Aside from their animal helpers to carry their supplies, and them on occasion, it was traversing terrain on foot that carried them to their new lives. Wagon trains were especially popular — chains of large, horse-drawn vehicles that carried large amounts of goods. Railways began to arrive not long after as the government offered free land to rail companies if they agreed to place track westwards.



To most, trains were a revolutionary way to travel. To others, they were a target

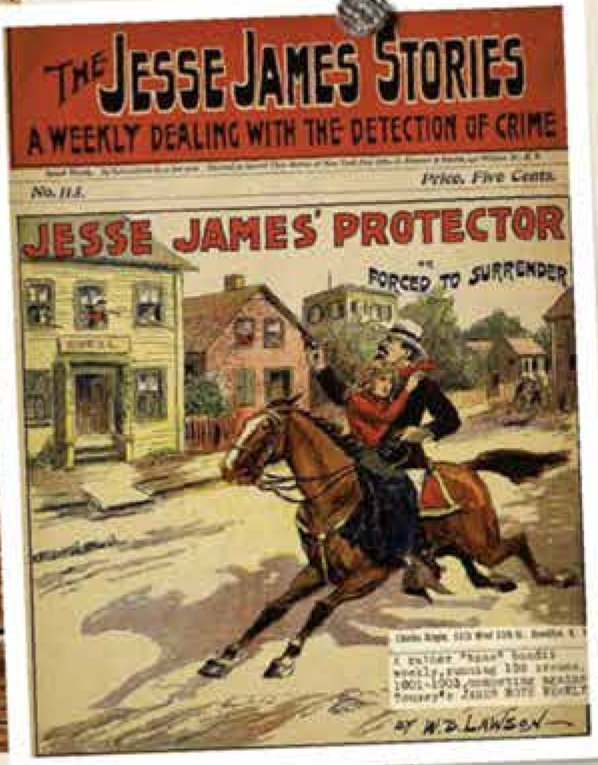
1853	1860	1862	1865	1865
Washington is organised as a territory to support new colonists.	The James Gang begins its notorious career of robbing trains, stagecoaches and banks.	The Homestead Act offers free western farming land, permitted the settlers stay for five years.	The American Civil War comes to an end. Some guerrilla soldiers become criminals in the west.	The editor of the *New York Tribune* advises readers: "Go West, young man".

DID YOU KNOW? *Cowboys aren't an American creation — the first were actually Mexican cattlemen known as vaqueros*

Infrastructure

The first settlers of the Old West would have loved the things we take for granted, like access to unlimited clean water and a grocery store. When they first arrived at the frontier they stored water taken from springs and they hunted and foraged for food and skins. Later they graduated to digging wells and forming crop and animal farms. Timber-framed homes followed, then the first giant distilleries were built to create precious, low-quality whiskey.

The western frontier was typically dry and arid, making access to clean water essential



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Entertainment

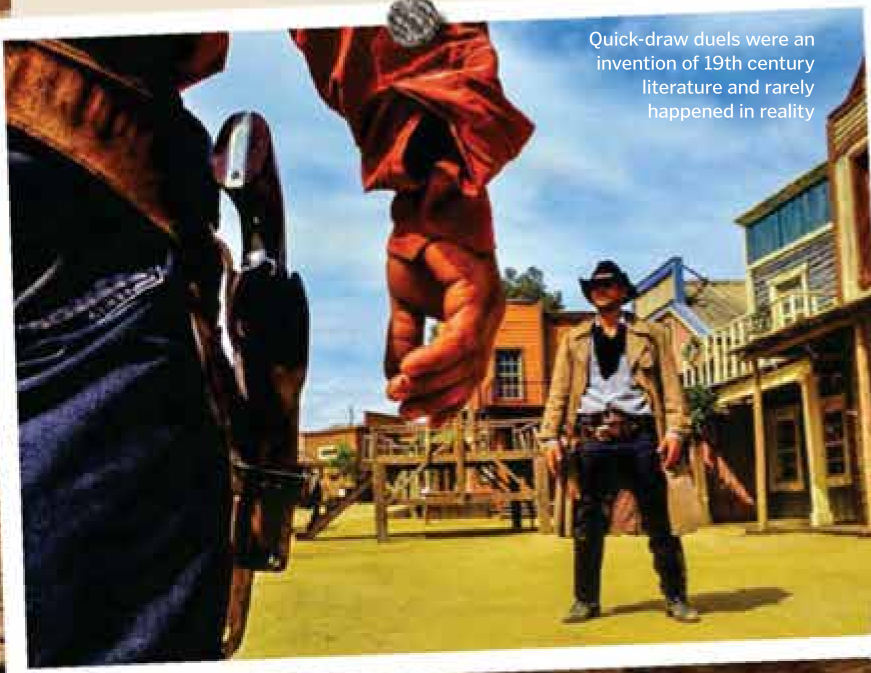
As fun as bounty hunting, duelling and simply firing a six-shooter must have been, most settlers had to find other means of entertainment in the Old West. Saloons were incredibly popular, and newspapers and 'dime novels' were widely read. In later years, travelling actors also toured the towns putting on shows, and homegrown entertainers soon began to appear.

Dime novels were incredibly popular in the Old West and inspired many future stories of the era

> "EARLY SALOONS WERE LITTLE MORE THAN TENTS"

Gunfights

Our romanticised idea of civilised duels in the Wild West are in truth quite far from the mark. Although single duels did happen rarely, the Hollywood depiction of two men stood facing each other in an empty street has its origins in 19th century dime novels, rather than actual historical records. Most gunfights were fought behind cover between groups of intoxicated men — there are many recorded examples of gamblers using guns to resolve a card game dispute!



Quick-draw duels were an invention of 19th century literature and rarely happened in reality

Communication

Some colonists travelled hundreds if not thousands of miles westwards to find work or claim land in the new territories. However, thanks to the invention of the telegraph in 1831, there was a much faster way of communicating with those left behind than simply sending a letter. Settlers could have their messages translated into Morse code and sent through electrical wires that connected to a distant station. This could then be decoded on the other side, resulting in an incredibly quick messaging method.

© Alamy; Getty; WIKI; Shutterstock

Before the telegraph, the Pony Express was used to deliver mail between the east and west of the US

1869	The US's first transcontinental railway running across the country is completed.
1881	Lawmen and ranchers clash over a silver mine at the OK Corral.
1883	Buffalo Bill Cody starts touring with his Wild West show.
1890	Idaho and Wyoming are admitted to the Union, becoming the 43rd and 44th states.
1907	The state of Oklahoma is created by combining the Indian and Oklahoma Territories.
1916	The last stage robbery of the Old West takes place in Jarbridge Canyon, Nevada.

The history of Edinburgh Castle

The scene of numerous sieges, Edinburgh Castle still stands proudly today as a symbol of military might

Sitting proudly atop of Castle Rock (a 700-million-year-old extinct volcano), Edinburgh Castle is one of the most iconic battlements on Earth and Scotland's second most visited tourist attraction.

Once the site of a fortification known as the 'Castle of the Maidens', the edifice that now stands on Castle Rock was constructed in the 12th century by David I, Prince of the Cumbrians and later King of the Scots from 1124–1153.

At over 131 metres above sea level and featuring looming sheer walls, the castle could not be stormed from any direction save the east. Yet despite posing a formidable obstacle to anyone wishing to take it, opponents knew that control of the castle meant control of the city.

Witness to numerous bloody encounters, the first major battle fought at Edinburgh Castle unfolded in 1296 following King Edward I of England's invasion of Scotland in March of that year, an incursion that sparked the First War of Scottish Independence. Following a three-day bombardment, the garrison inside the castle surrendered, but England's hold upon this strategically vital position would be anything but consistent in the centuries to follow.

Following the Scottish Wars for Independence, King David II, son of the fearsome warrior Robert the Bruce, had to contend with the damage inflicted upon Edinburgh Castle during the conflict. Eager to repair the broken fortress, King David oversaw a period of restoration that included the initial work to construct David's Tower, which was later replaced by the Half Moon Battery.

In the succeeding years Edinburgh Castle would witness further attempts by both the English and the Scots to wrest control of the castle and suffer the damage that such brutal clashes often caused.

Predominantly used to house prisoners of war captured during England's many foreign campaigns in the 18th and 19th centuries, the castle became a national monument in 1814. With over 1 million visitors a year, today Edinburgh Castle is a crucial part of the city's £1.6 billion tourist industry.

The Stone of Scone

Also known as the Stone of Destiny, this 66-centimetre-long block of red sandstone weighs in at around 152 kilograms and has seated numerous monarchs over the centuries.

Thought to have originated in Ireland, the stone was transported from Scotland to England in 1296 to be placed within the throne of King Edward I. It would reside in England for approximately 654 years until its illegal removal by four Scottish students in 1950.

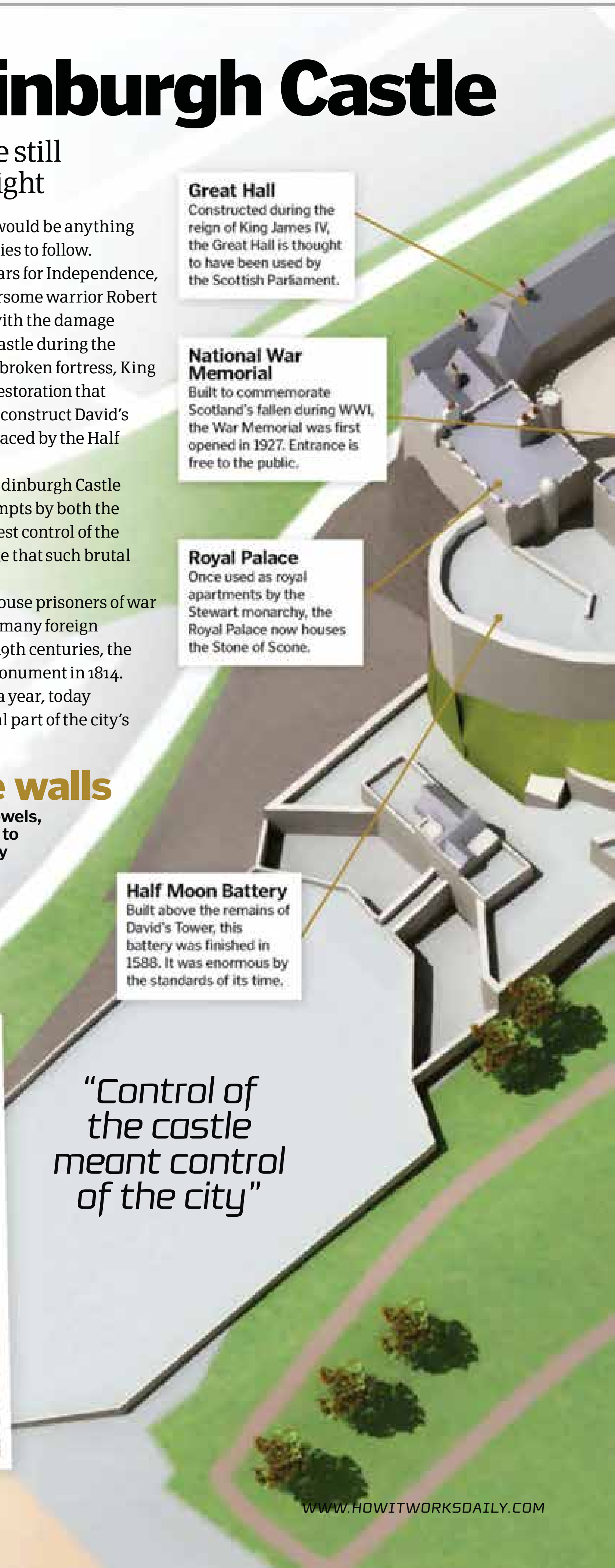
Attempting to return it to Scotland, the students accidentally broke the stone in two. It was found in 1951 and finally returned to its homeland. Residing today in the Crown Room of Edinburgh Castle, it will only leave Scotland when there is another royal coronation.

The Stone of Scone set into the Coronation Chair in Westminster, London, in 1855

Beyond the walls

From cannons to crown jewels, Edinburgh Castle is home to much of Scotland's history

A key leader in the Scottish Wars of Independence, a statue of William Wallace stands before the castle gates



Great Hall
Constructed during the reign of King James IV, the Great Hall is thought to have been used by the Scottish Parliament.

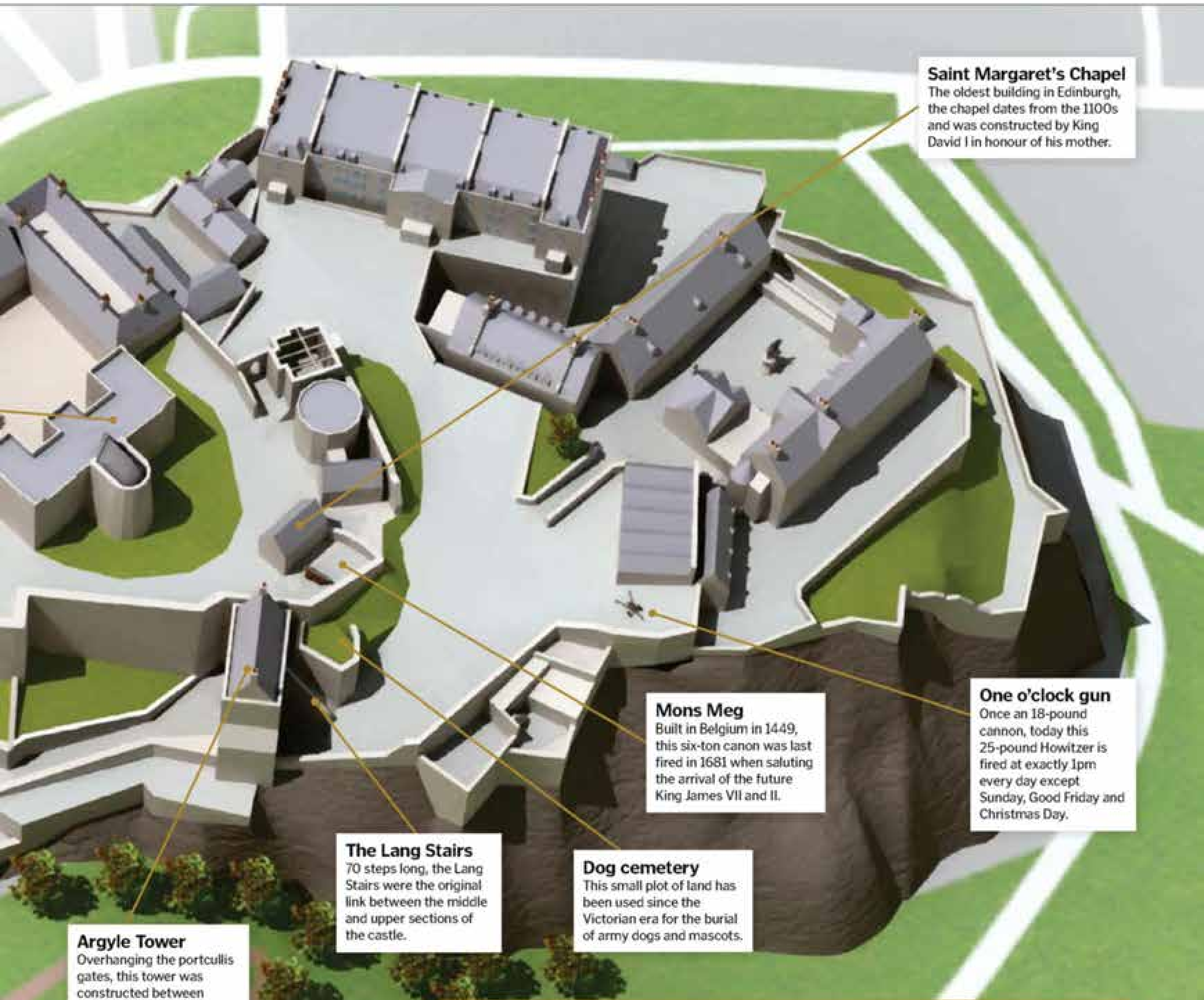
National War Memorial
Built to commemorate Scotland's fallen during WWI, the War Memorial was first opened in 1927. Entrance is free to the public.

Royal Palace
Once used as royal apartments by the Stewart monarchy, the Royal Palace now houses the Stone of Scone.

Half Moon Battery
Built above the remains of David's Tower, this battery was finished in 1588. It was enormous by the standards of its time.

"Control of the castle meant control of the city"

DID YOU KNOW? *It's considered bad luck for students of Edinburgh University to pass through the castle gates*



Saint Margaret's Chapel
The oldest building in Edinburgh, the chapel dates from the 1100s and was constructed by King David I in honour of his mother.

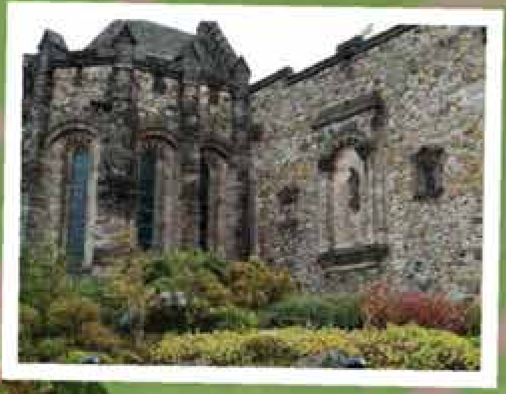
Mons Meg
Built in Belgium in 1449, this six-ton canon was last fired in 1681 when saluting the arrival of the future King James VII and II.

One o'clock gun
Once an 18-pound cannon, today this 25-pound Howitzer is fired at exactly 1pm every day except Sunday, Good Friday and Christmas Day.

The Lang Stairs
70 steps long, the Lang Stairs were the original link between the middle and upper sections of the castle.

Dog cemetery
This small plot of land has been used since the Victorian era for the burial of army dogs and mascots.

Argyle Tower
Overhanging the portcullis gates, this tower was constructed between 1886–1887 and named after the 9th Earl of Argyll.



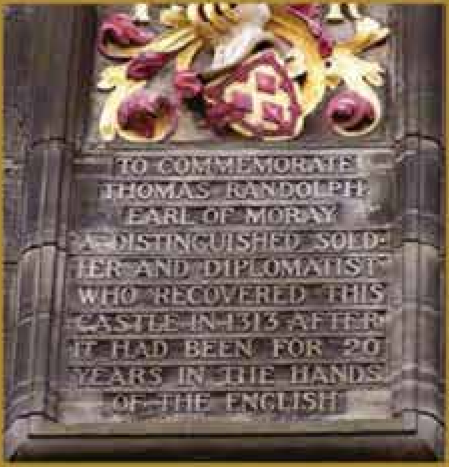
Despite its royal heritage, Saint Margaret's Chapel was used to store gunpowder in the 16th century

Thomas Randolph, captor of the castle

Born in 1278, Thomas Randolph, 1st Earl of Moray was the nephew of Robert the Bruce and a key figure in the Wars for Independence.

Supportive of his uncle's rebellion in 1306, Randolph was imprisoned by the English following the Battle of Methven in that same year and fought for King Edward I until he was recaptured by the Scots in 1308.

Installed as Earl of Moray in 1312, Randolph would repay his uncle's kindness in 1314 when he led a band of 20 men on a daring raid to retake Edinburgh Castle. Scaling the seemingly impassable walls, Randolph's audacious plan worked as the English were completely taken by surprise. With the castle back in Scottish hands, Randolph went on to fight courageously in the crushing victory over the English at Bannockburn three months later.



TO COMMEMORATE
THOMAS RANDOLPH
EARL OF MORAY
A DISTINGUISHED SOLDIER
AND DIPLOMATIST
WHO RECOVERED THIS
CASTLE IN 1313 AFTER
IT HAD BEEN FOR 20
YEARS IN THE HANDS
OF THE ENGLISH

An inscription commemorating Randolph's raid. The date is incorrect due to calendar changes

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DEADLIEST DICTAT☠RS

Famine, oppression, genocide. Meet the men who oversaw the world's most lethal regimes

☠ = 2 million

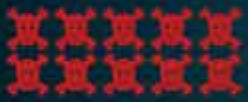
Joseph Stalin

Soviet Union / 1929-53

To revolutionise his nation, Stalin imposed policies that moved people from the countryside into cities. Many starved, and those who opposed were imprisoned in brutal labour camps called gulags.

Estimated death toll

20 million



Adolf Hitler

Germany / 1933-45

Hitler's forces committed genocide across vast swathes of Europe and millions of prisoners were killed in Nazi concentration and death camps.

Estimated death toll

14 million

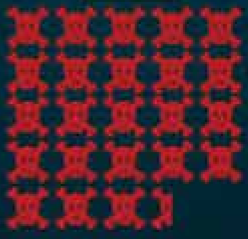
Mao Zedong

China / 1949-76

Zedong decided to ban private farming as part of the Great Leap Forward, a cultural revolution focused on industry. The campaign led to mass starvation as widespread famine gripped much of the country.

Estimated death toll

47 million



Chiang Kai-shek

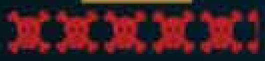
China / 1928-49

Taiwan / 1949-75

Beginning his career as a revolutionary, Chiang saw casualties rise under his rule throughout World War II — when his country fought against Japan — and during an ensuing civil war.

Estimated death toll

10.5 million



King Leopold II

Congo Free State / 1885-1908

The second king of Belgium established a colony in Africa named the Congo Free State. The native Africans were enslaved and subjected to extremely harsh rule.

Estimated death toll

10.4 million

Skilled armourers of a town or city would all belong to the same guild

What were medieval guilds?

Meet the groups of merchants and skilled craftsmen that became prominent in civic life

Many historians believe that guilds first arrived in Europe during the 10th and 11th centuries as the Dark Ages ended and towns began to grow. At this point in time, travelling merchants would make potentially perilous journeys from town to town with their goods in tow, hoping that they wouldn't fall prey to bandits or a greedy landowner. Eventually, these merchants banded together to protect their goods, and the merchant's guild was born.

Within the towns, crafts guilds soon started to appear. Like the merchants, practisers of a particular trade such as blacksmithing, baking or soap making realised that they all benefitted from forming a guild. Under the guidance of appointed guild masters selling prices became regulated, all items were checked to ensure they were at a high standard and only guild members were permitted to craft in the town.

This team ethic allowed all members of the guild to work and make a wage, stopped outsiders from taking any trade, and made sure the customer always got what they paid for. Today's labour unions are the guild's enduring legacy.

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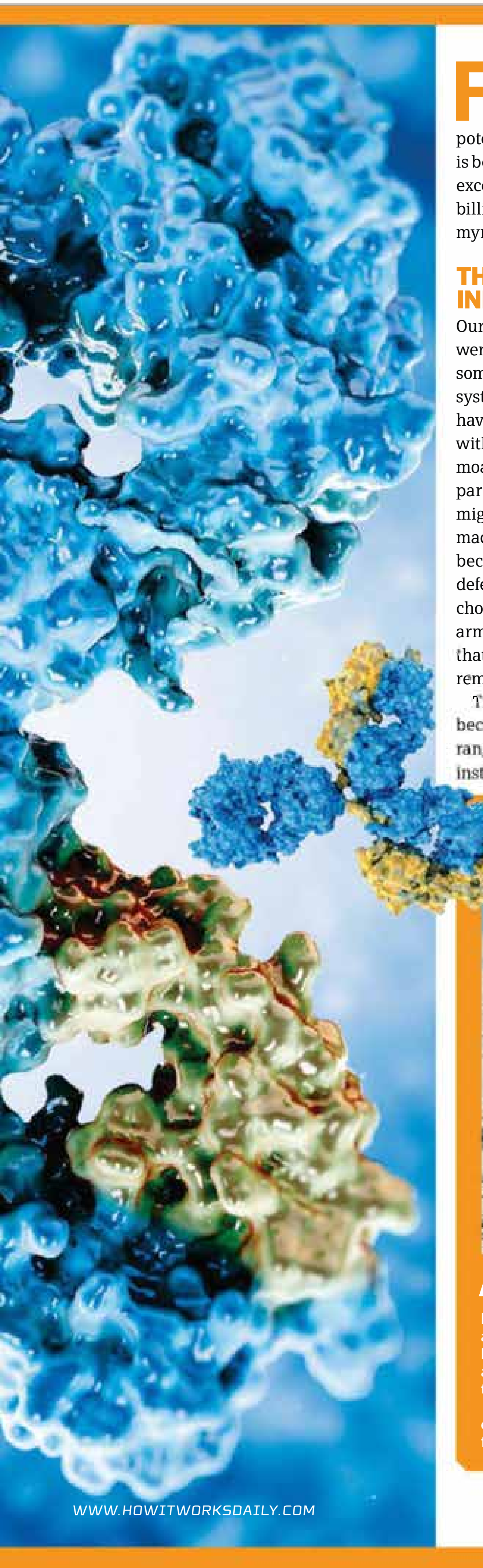
THE IMMUNE SYSTEM

Your body under siege — discover how your immune army defends and protects you

MEET THE EXPERT

Dr Catherine Carver is a writer and recovering medic and academic. She completed a Master's degree at Harvard and was shortlisted for the *Guardian*'s 2012 Science Writing Prize. Her first book, *Immune*, is out now and offers a fun-filled journey through the immune system.



From cleaning the kitchen sink to having sex, everything we do exposes us to invaders. Yet we are safe. Most of the time potential invaders' attempts are thwarted. This is because the human body is like an exceedingly well-fortified castle, defended by billions of soldiers, and I'd like to reveal its myriad of miracles and secrets to you.

THE DARK ARTS OF THE INNATE DEFENCES

Our story begins with a feat of imagination: if we were to put 100 people in a room, hand them some crayons and ask them to draw a defence system, what might you expect to see? You can have a pretty good guess — probably castles with high, impenetrable walls surrounded by moats (shark-infested, among the more creative participants). A less historically inclined artist might draw us an array of lasers, rockets and machine guns. These are relatively predictable because even without knowing what you're defending against, there are certain solid choices you can make. This is akin to the 'innate' arm of the immune system — the set of defences that we are born with and which essentially remain the same throughout our lives.

The innate system is the first line of defence because it's already set up and ready to take on a range of common pathological patterns. For instance, all invaders need an entry point — it doesn't matter if you're a tiny virus or a massive worm, you need a way in — so part of the innate immune system's role is to maintain robust control of the body's entry and exit points.

Cue our first innate defence: skin. Skin is the largest human organ; if you were to peel yours off you'd lose about 12 kilograms instantly. The skin on the soles of your feet is eight-times thicker than the skin on your eyelids, but every inch of it is an exquisite barrier that keeps unwanted invaders out.

While snakes shed their skins in one go, we slough off old skin continuously and rain it down at a rate of roughly 50,000 cells a minute. Given that fact, it's almost unsurprising that dead skin accounts for about a billion tons of dust in the atmosphere. Unsurprising, but gross. On the plus side, this constant turnover of cells means the barrier is continually replenished, keeping our skin healthy and keeping the billions of bacteria slathered over its surface out.

Unfortunately, we can't be truly impenetrable. We need to let in food and water and air and light, and we need to let some things out, too. So we have a body full of holes, which is deeply inconvenient from a security perspective. But we

> *"The innate system is the first line of defence"*

Sneezing is a familiar symptom for people with a pollen allergy, such as hayfever

An epidemic of allergies

Do you have any allergies? If so, you're not alone; according to Allergy UK, "More than 150 million Europeans suffer from chronic allergic diseases, and the current prediction is that by 2025 half of the entire EU population will be affected."

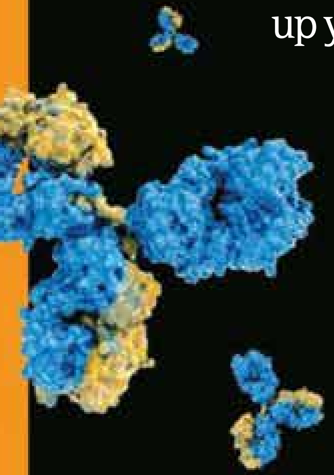
90 per cent of food allergies are caused by just eight things: milk, eggs, peanuts, nuts from trees, fish, shellfish, soy and wheat. All of these allergies are caused by the immune system reacting to a harmless substance by launching an unwarranted attack that can cause symptoms from a rash to a life-threatening airway blockage.

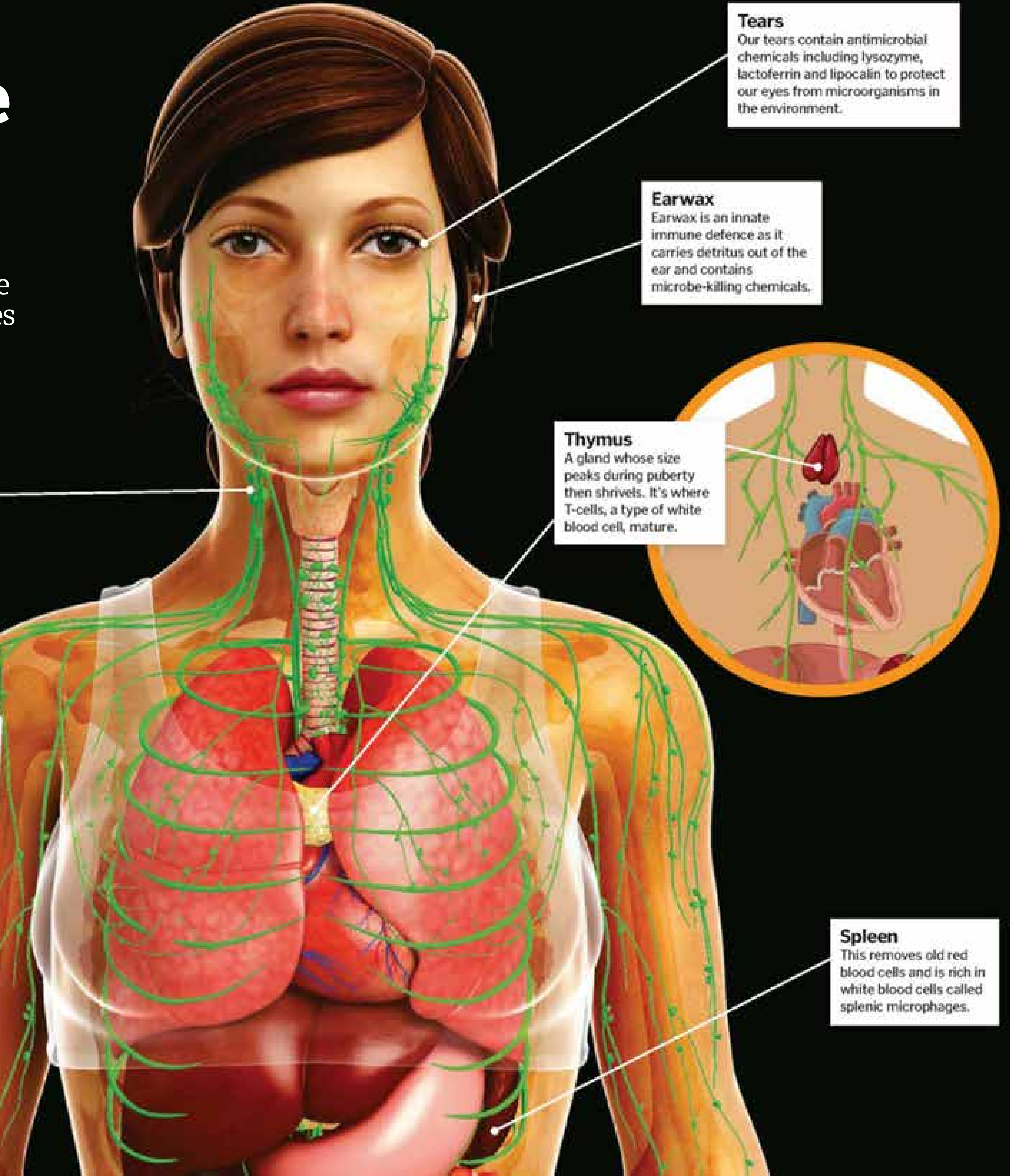
While we don't know why the immune system does this, we do know some people are more genetically susceptible to allergies because they run in families.

© Thinkstock; Getty

Your immune system

Discover some of the different organs and components that make up your body's defences





Tears
Our tears contain antimicrobial chemicals including lysozyme, lactoferrin and lipocalin to protect our eyes from microorganisms in the environment.

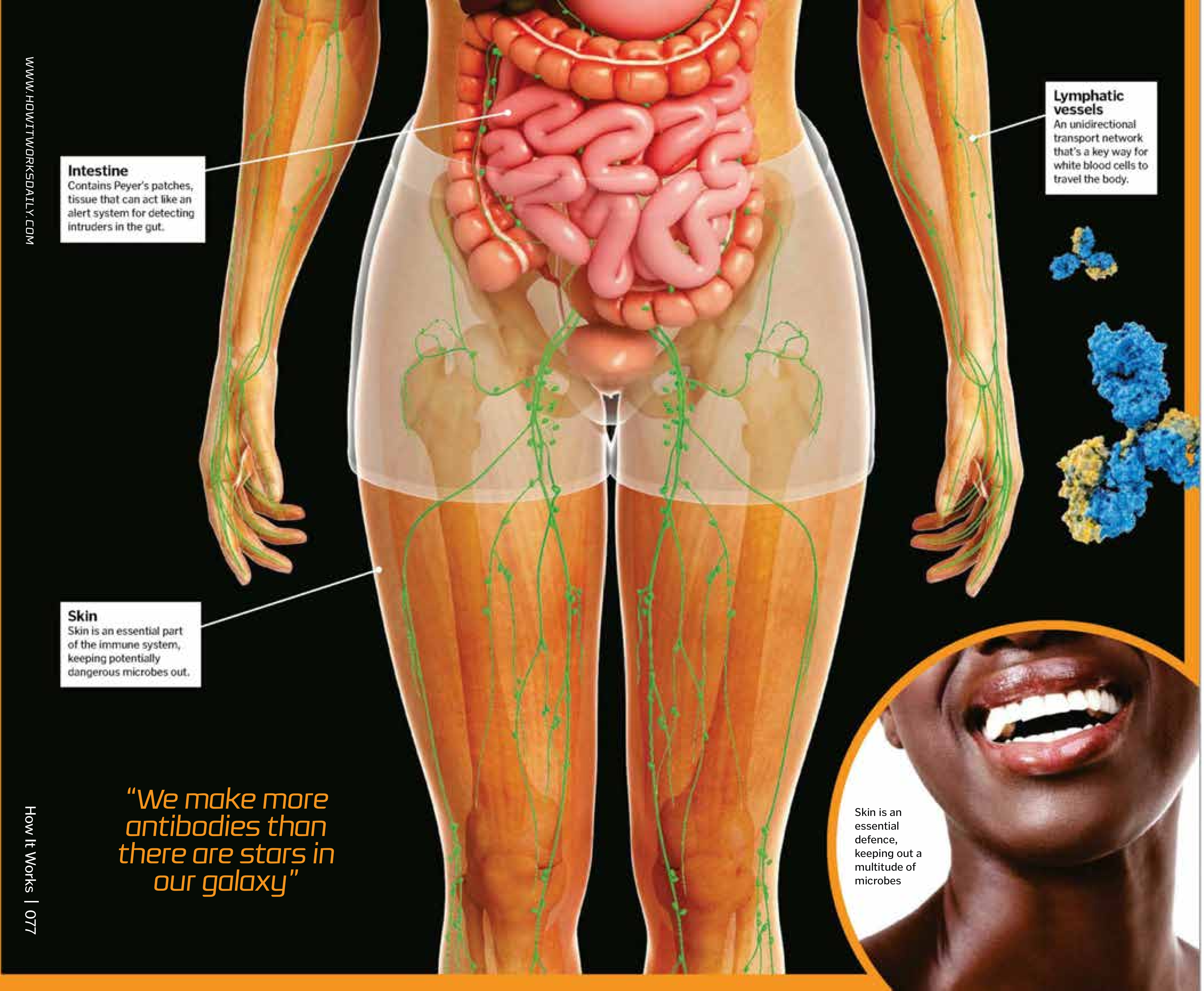
Earwax
Earwax is an innate immune defence as it carries detritus out of the ear and contains microbe-killing chemicals.

Lymph nodes
This is where special white blood cells can be presented with foreign material like bacteria and set off to kill it.

Thymus
A gland whose size peaks during puberty then shrivels. It's where T-cells, a type of white blood cell, mature.

Spleen
This removes old red blood cells and is rich in white blood cells called splenic microphages.

The immune system is critical to the success or failure of organ transplants



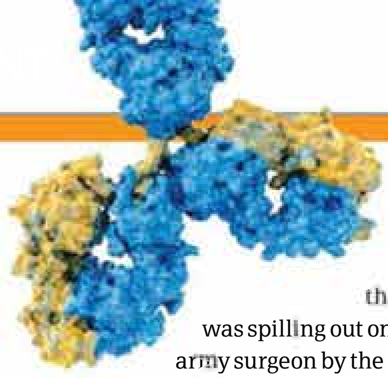
Lymphatic vessels
An unidirectional transport network that's a key way for white blood cells to travel the body.

Intestine
Contains Peyer's patches, tissue that can act like an alert system for detecting intruders in the gut.

Skin
Skin is an essential part of the immune system, keeping potentially dangerous microbes out.

Skin is an essential defence, keeping out a multitude of microbes

"We make more antibodies than there are stars in our galaxy"



have clever holes. Take your mouth: every time you inhale you are sucking about 10,000 bacteria into your lungs. Thankfully your airways are exceedingly well booby-trapped passages lined with goblet cells, which secrete a fine layer of mucus to trap dirt and bacteria. The dirty mucus is then escorted out by microscopic whip-like structures called cilia, which stick out from the lining of the airways and beat 1,000–1,500 times per minute, forcing the mucus up and out of the lungs in waves at a rate of two to three centimetres per minute.

While the lung escorts invaders out in an orderly fashion, the gut takes a more medieval approach to border control: acid. This acid is the reason the normal stomach is an unwelcoming pH 2, capable of disintegrating many of the microorganisms that land in it. The discovery of this acid has a rather gruesome history.

The story begins in June 1822 on the island of Michilimackinac in the wilds of Michigan. At the time this lush green island, christened 'the great turtle' by the Ottawa and Chippewa tribes, was the main trading post of the American Fur Company (the brainchild of America's first multimillionaire, John Jacob Astor).

It was while standing in line at the Fur Company store that a 20-year-old trapper by the name of Alexis St Martin was accidentally shot. The only doctor on the island arrived to a scene worthy of any horror movie: 'A portion of the lungs as large as a turkey's egg protruding through the external wound'. St Martin also had a hole in his stomach through which his breakfast was spilling out on to his shirt. His doctor, an army surgeon by the name of Beaumont, thought St Martin had little chance of survival but astoundingly, with the care of Beaumont, St Martin slowly became whole again. Well, almost. The hole in his stomach didn't fully heal, and St Martin declined offers from Beaumont to stitch it shut. This physical quirk changed not only the course of their relationship but also the history of science.

Over the course of several years and 238 experiments, Beaumont extracted acid and introduced medicine and food into the hole in St Martin's stomach. This led to Dr Beaumont's seminal publication on the subject, including conformation that hydrochloric acid is the most important acid in the stomach.

ADAPTIVE ASSASSINS

Let's imagine a different task from our original artistic efforts. If we had given our 100 people the challenge of drawing a defence system against a very specific threat, they would have drawn rather different defences. For instance, garlic and holy water would be essential in an anti-Dracula defence system but would be frankly embarrassing in the face of Darth Vader. This opponent-specific weapons selection resembles the 'adaptive' arm of our immune response, which complements the breadth of the innate response by being able to recognise and respond to specific threats.

Included within the adaptive system are antibodies, which are Y-shaped proteins that can latch onto bacteria, parasites and viruses and label them for destruction by our white blood cells.

Our ability to make a diverse array of antibodies is legendary. We can make over 1 trillion different antibodies — that's more antibodies than there are stars in our galaxy. Making this level of diversity means that, given

David Vetter lived life in a bubble because he didn't have an immune system to defend him

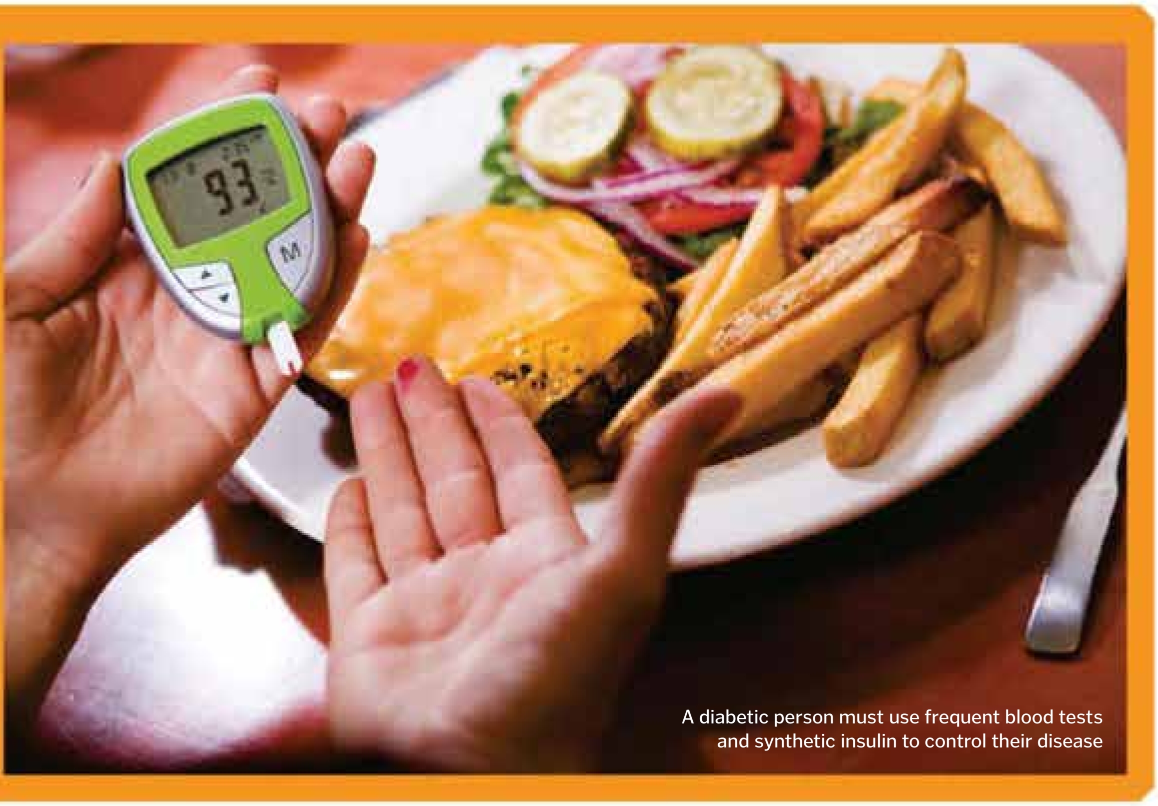
> "The immune system influences everything from pregnancy to organ transplantation"

Autoimmune diseases

Sometimes, the immune system turns on the very body it's designed to protect. We don't know why, but white blood cells can fail to recognise the body's own cells as belonging to it. The classic example is type 1 diabetes, where the immune system attacks the pancreas.

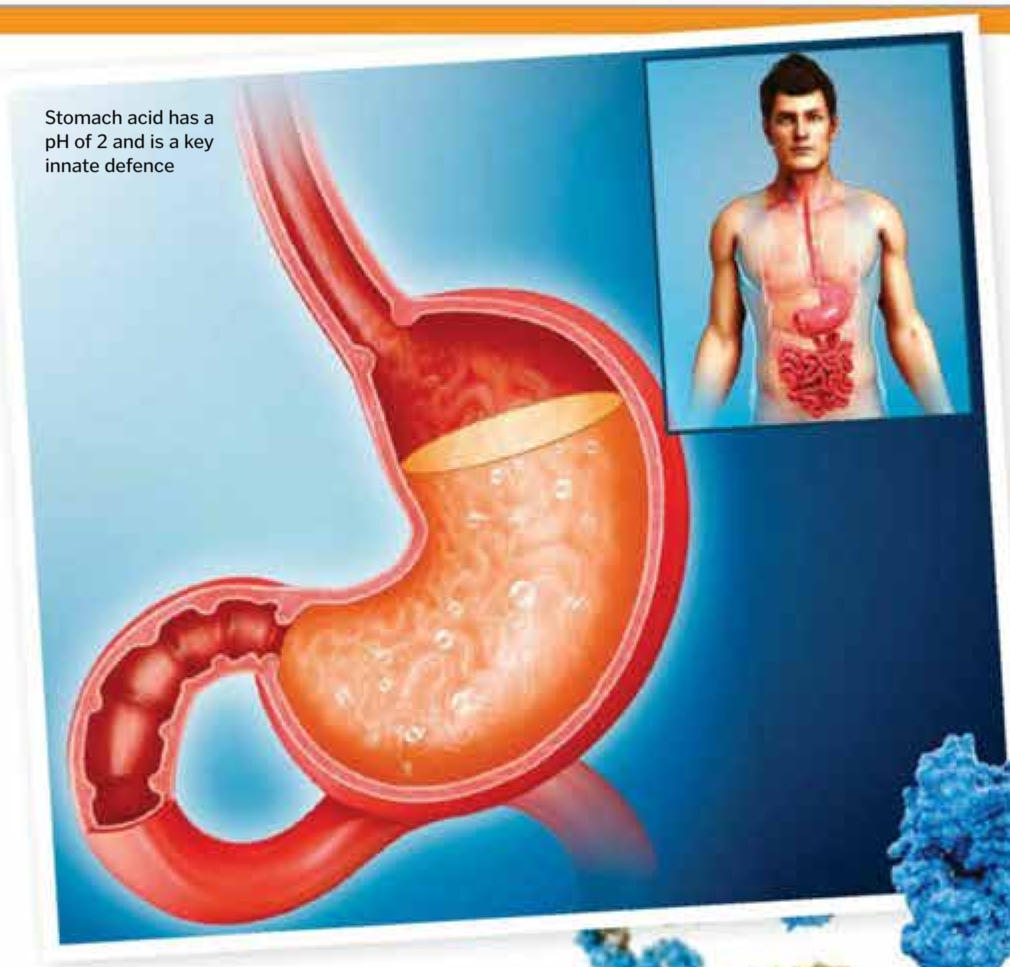
By systematically destroying the beta cells of the pancreas, the immune system renders the body incapable of making insulin, a hormone essential to controlling blood sugar levels. A diabetic person must use frequent blood tests and synthetic insulin to reduce the risk of serious consequences, including going blind or needing to have limbs amputated.

The severity and commonality of this disease is inspiring many innovative solutions, including in the US, where a bionic pancreas is currently under development.



A diabetic person must use frequent blood tests and synthetic insulin to control their disease

DID YOU KNOW? *The night before giving birth, David Vetter's mum had to sleep on sterile sheets and eat sterile food*



Stomach acid has a pH of 2 and is a key innate defence

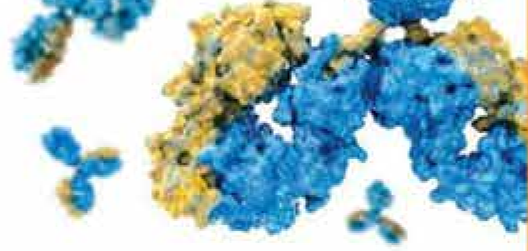
enough time, our body can develop antibodies against everything from the common cold to the Black Death.

Alas, sometimes infections move too quickly and kill us before we have a chance to develop tailored antibodies. Other infections change their shape to evade our adaptive immune response. HIV is well known for it's ability to mutate, changing its surface shape and making it exceedingly difficult for our immune system to make new antibodies quick enough to adapt to HIV's changing face.

TRANSPLANTS

The immune system not only defends and protects us; it also plays a key part in a range of life experiences, from pregnancy to organ transplantation. For example, research suggests the immune system may play a key part in whether a fertilised egg safely implants into the womb and therefore whether a pregnancy proceeds or tragically ends in miscarriage.

In the example of transplants, our immune system can recognise the new organ as foreign and damage it until it can't function, a process called rejection. One option to attempt to avoid transplant rejection is to use cells from the recipient's own body, known as 'self-cells', because the immune system won't see the new tissue as foreign and attack it. For instance, people who lose a thumb can understandably struggle with using their hand. Some therefore opt to have something called a 'thoe' created by transplanting their big toe onto their hand. This may sound unusual but the thoe improves the range of movements the hand can achieve without being a massive loss to the foot.



An even more impressive application of using self-cells to help avoid rejection comes from a rather more intimate area. In 2014, doctors from Mexico and the US operated on four young women affected by Mayer-Rokitansky-Küster-Hauser Syndrome (MRKHS). This rare syndrome causes girls to be born with a completely or partially absent vagina. The surgeons in this case took cell samples from each patient and then grew these cells on a bespoke biodegradable scaffold. After an average of 6.75 years of follow up, all four young women were happy with their transplants, and none were rejected by their immune systems.

DEFENCELESS

When we consider things like transplant rejection, the immune system can seem more like a foe than a friend. However, the tale of David Vetter, a boy without a functioning immune system, is a stark reminder of how dependent we are on our defences.

David was in this world for just 20 seconds before he was transferred to a sterile bubble, where he spent the rest of his life to protect him from the microbes in the environment that would have killed him within days. Sadly he died at the age of just 12 when a failed bone marrow transplant gave him an infection. He never got to drink Coca Cola, one of his life aspirations, and the closest he got to playing in the garden depended on a $50,000 (£38,780) NASA engineered suit, which he was only able to use six times before outgrowing it.

As David's story tragically reminds us, our defences are absolutely essential to keeping us alive. It is thanks to our immune systems that we are not just alive but thrive in this dirty, beautiful, bug-filled world.

Immunology, sex and death

Pity the poor male brown antechinus, a small marsupial found in southeast Australia. In preparation for the short breeding season he stops making sperm and his testes disintegrate, leaving him with stores of sperm and a need to procreate. And so he does, spending up to 14 hours a day mating. But all this comes at a cost in the form of massively raised levels of cortisol, a stress hormone.

High cortisol leads to severe suppression of immune messenger chemicals, which means that when a male brown antechinus gets injured or ill it can't mount an immune response. This ultimately leads to the death of our valiant, virile little friend.

The male brown antechinus goes on a mating frenzy that ultimately ends in his demise

Learn more

For more fascinating facts about the immune system, Catherine's book *Immune: How Your Body Defends and Protects You* is out now, published by Bloomsbury Sigma.

The immortal cells of Henrietta Lacks

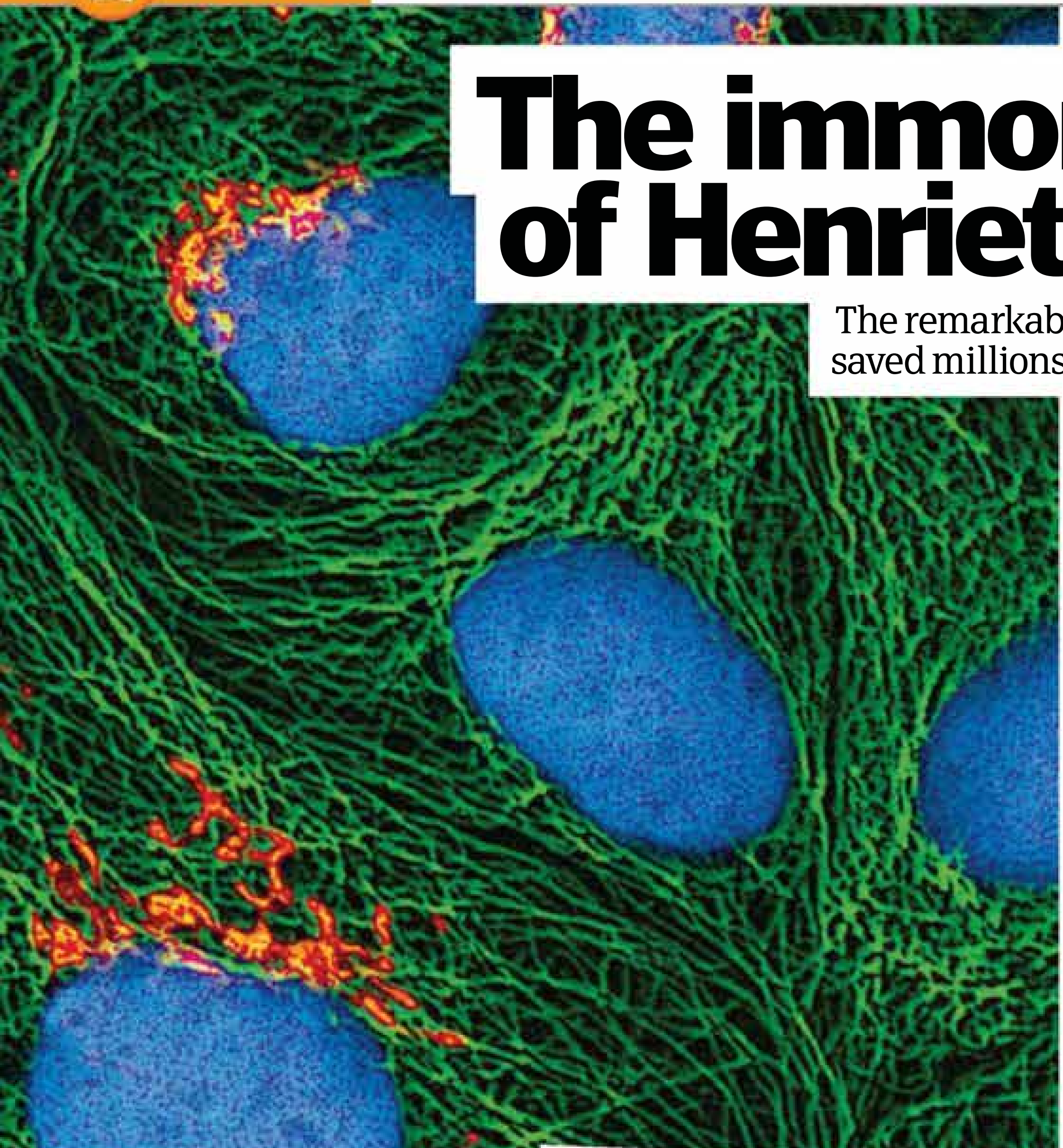
The remarkable story of the woman who has saved millions of lives from beyond the grave

When cell biologist George Otto Gey received a new sample of cervical cancer cells taken from a deceased patient at Baltimore's John Hopkins Hospital in 1951, he had already prepared himself for failure. For decades, many similar cell samples had passed through his lab, but instead of growing as he had hoped all had died within a few days. This time, though, something was different. These cells not only stayed alive but began to double every 24 hours, creating an endless supply that could be studied outside of the human body — and no one knew why.

Gey named this new line of cells 'HeLa', a code name for Henrietta Lacks, the woman from who the cells had originated, but no one would discover her real name for another two decades. Rather than selling the cells to make a profit, Gey decided to give them out freely for the benefit of science, and they were soon sent to labs all over the world. For the first time, scientists could observe how viruses such as measles, mumps and polio affected human cells, helping them conduct vital research and even develop life-saving vaccines.

Realising the importance of HeLa, the US government decided to set up a cell culture factory, which at its peak produced six trillion of the cells every week. However, because HeLa was so aggressive, it began to contaminate and take over any other cell line it came into contact with. To help them determine if a cell was HeLa or not, scientists needed more genetic information, and so it was then, in the early 1970s, that the cells' origins were revealed.

As doctors had not been required to get consent when taking cell samples from patients, Henrietta's family had no idea about her incredible legacy until they were asked by scientists if they could supply blood samples in 1973. They soon discovered that not only had their relative not been recognised for her contribution to science, but they themselves had been living in poverty and without healthcare while others profited from her cells, which had by then become commercialised. Then, in 2013, Henrietta's genome was published online without their permission, revealing personal information about their own chances of developing certain health issues to the world.



More than 60,000 scientific articles have been published about research performed with HeLa cells

Henrietta Lacks, an African-American tobacco farmer from Baltimore, died aged 31

DID YOU KNOW? *HeLa cells can float on dust particles, helping them to contaminate other cell lines easily*

As a result, the HeLa genome committee was established, finally giving the Lacks family some control over access to Henrietta's DNA. Henrietta herself also finally received the recognition she deserved and was awarded an honorary doctorate and had scholarships and school buildings named after her. Today, her incredible cells continue to aid our knowledge of human biology and help save millions of lives around the world.

> "The cells not only stayed alive but began to double every 24 hours"

1 Polio vaccine

When HeLa cells were first discovered, the world was in the middle of a polio epidemic. Jonas Salk was one of the many researchers desperately trying to develop a vaccine, and when he got hold of some HeLa cells they finally enabled him to reproduce the infectious poliovirus on a large scale. This helped him to test a vaccine that has now eradicated polio in much of the Western Hemisphere.

2 In vitro fertilization (IVF)

Dr Howard Jones, the physician who examined Henrietta Lacks at John Hopkins Hospital, went on to oversee research using HeLa cells that resulted in the world's first successful fertilization of a human egg outside of the body. This led to the birth of the US's first 'test tube baby' in 1981.

3 Cancer research

In the early 1980s, German virologist Harald zur Hausen discovered that HeLa cells contained copies of a strain of human papillomavirus (HPV) that caused the type of cervical cancer that killed Henrietta. Using this knowledge scientists were able to develop HPV vaccines, which have reduced the cases of infection in teenage girls by almost two-thirds. Hausen won a Nobel prize in 2008 for his game-changing discovery.

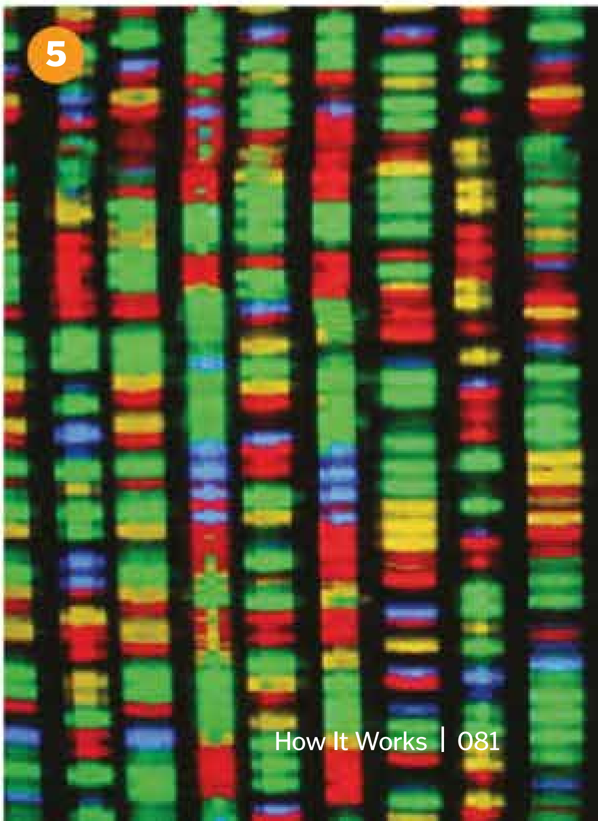
4 Human space travel

In 1957, HeLa cells were sent into space onboard the second Russian satellite ever put into orbit. This enabled scientists to observe the effects of space travel on human cells, paving the way for human astronauts. HeLa cells were also sent up with the first humans in space and were found to divide more quickly in zero gravity.

5 Genome mapping

In 1965, scientists Henry Harris and John Watkins fused HeLa cells with mouse cells, creating the first human-animal hybrid cells. These enabled scientists to study which proteins or gene functions were produced by which chromosomes, later making it possible to map the entire human genome. This set the stage for the Human Genome Project, an international scientific research project aiming to identify all of the genes in the human genome.

© National Institutes of Health (NIH); Alamy; Getty



What are electrolytes?

We need these tiny ions to keep our muscles and nerves moving

Our bodies are huge biochemical batteries, and to keep our nerves firing, our muscles moving and our hearts beating, we need to maintain the right balance of ions, which are called electrolytes. Some of the most important are sodium (Na+), potassium (K+), calcium (Ca2+), chloride (Cl-), and bicarbonate (HCO3-).

Sodium and potassium are involved in a pump system that maintains an electrical potential across the walls of your nerves and muscles. When nerves fire, gates open and the ions rush through, triggering an electrical impulse. Negatively charged chloride ions balance sodium and potassium — calcium is involved in muscle contraction and triggering the release of chemical messages from the end of nerves, and bicarbonate works as a pH buffer, helping to keep the acidity of your body in check.

When you sweat you don't just lose water — you lose these crucial electrolytes too. And if you only drink pure water when you're done exercising, you aren't replacing them. You can regain lost electrolytes from your food, but elite athletes sometimes benefit from sports drinks with added minerals to help them recharge on the go.

Sports drinks can help elite athletes to recover lost electrolytes

Reusing bottles

Is it really dangerous to rinse and refill disposable plastic water bottles?

Refilling water bottles is more complicated than it first appears

Bacteria can grow on the surface of plastics, so washing your bottles between use is a must; a bottle brush and hot soapy water can help you get into all of the nooks and crannies. However, disposable bottles are usually made from thin polyethylene terephthalate (PET), which will start to crease and crack with time, providing even more places for bacteria to hide and grow.

You might sometimes hear that components from plastics will leach into your drinks over time too. In the UK, the Food Standards Agency and the European Commission regulate the materials that come into contact with our food and drink. They set rules about the types of plastics that can and cannot be used and the acceptable limits for the amount of plastic that can safely enter food.

Bisphenol A (BPA) is the chemical that's most often mentioned, but so far the evidence that it causes harm to people isn't conclusive. Plus, it's used in the manufacture of rigid polycarbonate bottles, not disposable PET ones. If you're worried, your best bet is to get hold of a reusable aluminium, steel or glass bottle and avoid the plastic conundrum altogether.

© Getty

Pandemic

Work together to prevent a global catastrophe

■ Publisher: **Z-Man Games** ■ Price: **£29.99 / $39.99** ■ Number of players: **2-4** ■ Ages: **8+** ■ Typical game time: **40–60 minutes**

Board games usually pit players against each other in a test of adversarial skill, tactical cunning and often sheer resilience. So by inviting players to use those same traits to work together against an external threat, *Pandemic* is unique among mainstream board games.

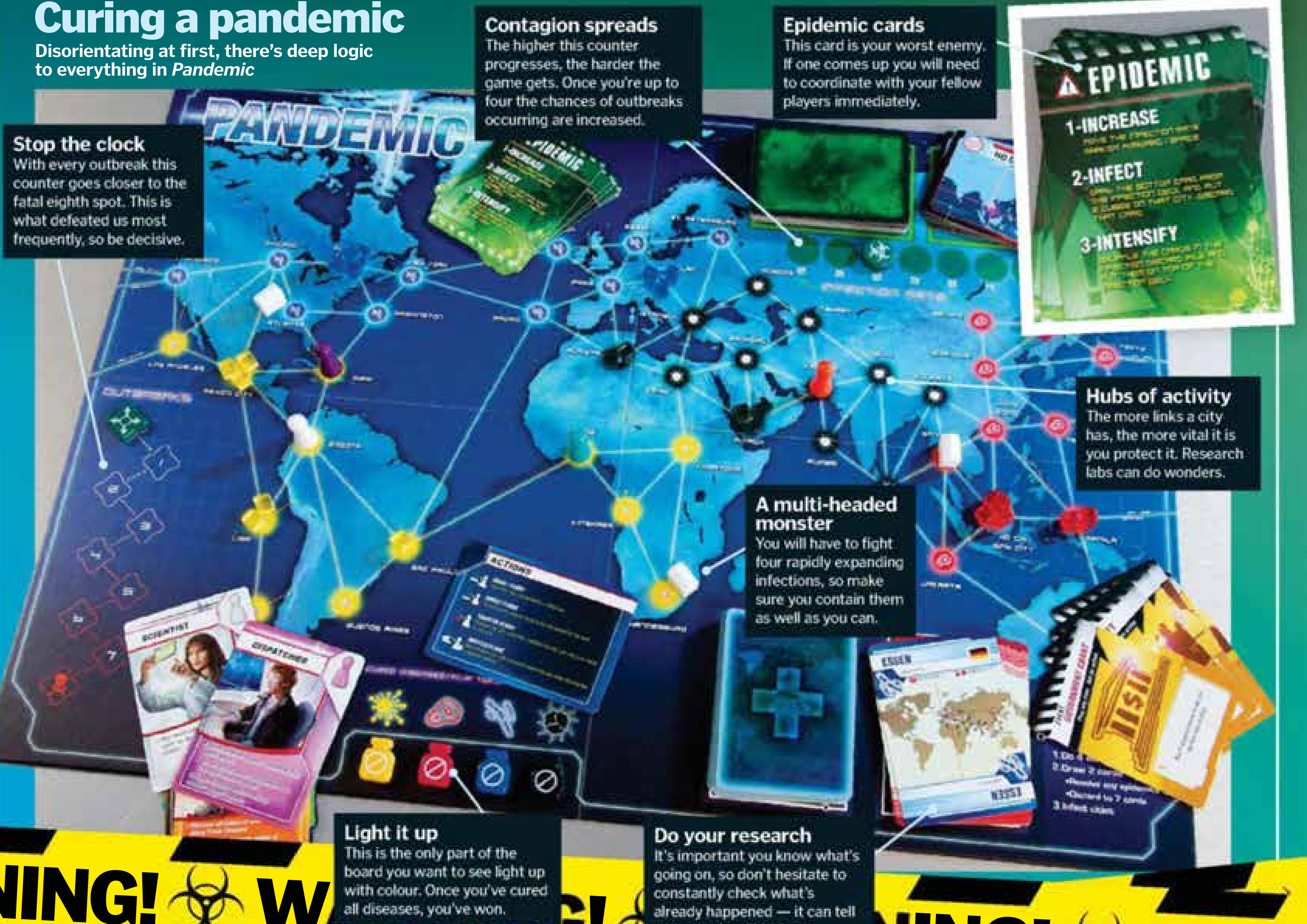
The game entails between two and four players each taking on a distinct role in a fight to save humanity from a deadly outbreak. You will need to employ the same logical skill you have to use to obliterate your opponent in *Risk* to help each other out as infections break out across the globe, threatening to become an unstoppable pandemic of apocalyptic proportions.

Every time we played it rapidly became a race against time, as outbreaks can (and do) spread quickly. There is absolutely no time for any dawdling or indirect action, whether you're a medic, scientist or any of the seven different roles available to play, even when playing it at an 'Introductory' level.

With each player having to complete four actions a turn, use and draw multiple cards, and consider not only their own plan but that of everyone at the table, the learning curve is steep, but once we got our heads around the main gameplay, it became a truly exciting evening of games and fun — and the potential annihilation of humanity, of course.

Curing a pandemic

Disorientating at first, there's deep logic to everything in *Pandemic*



Stop the clock
With every outbreak this counter goes closer to the fatal eighth spot. This is what defeated us most frequently, so be decisive.

Contagion spreads
The higher this counter progresses, the harder the game gets. Once you're up to four the chances of outbreaks occurring are increased.

Epidemic cards
This card is your worst enemy. If one comes up you will need to coordinate with your fellow players immediately.

Hubs of activity
The more links a city has, the more vital it is you protect it. Research labs can do wonders.

A multi-headed monster
You will have to fight four rapidly expanding infections, so make sure you contain them as well as you can.

Light it up
This is the only part of the board you want to see light up with colour. Once you've cured all diseases, you've won.

Do your research
It's important you know what's going on, so don't hesitate to constantly check what's already happened — it can tell you what is still to come.

BRAIN DUMP

Because enquiring minds need to know...

Want answers?

Send your questions to...

How It Works magazine @HowItWorksmag

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MEET THE EXPERTS

Who's answering your questions this month?

Laura Mears

Laura studied biomedical science at King's College London and has a master's from Cambridge. She escaped the lab to pursue a career in science communication and also develops educational video games.

Alex Franklin-Cheung

Having earned degrees from the University of Nottingham and Imperial College London, Alex has worked at many prestigious institutions, including CERN, London's Science Museum and the Institute of Physics.

Tom Lean

Tom is a historian of science at the British Library where he works on oral history projects. He recently published his first book, *Electronic Dreams: How 1980s Britain Learned To Love The Home Computer.*

Katy Sheen

Katy studied genetics at university and is a former **How It Works** team member. She now works for a biomedical journal, where she enjoys learning about the brilliant and bizarre science of the human body.

Joanna Stass

Having been a writer and editor for a number of years, **How It Works** alumnus Jo has picked up plenty of fascinating facts. She is particularly interested in natural world wonders, innovations in technology and adorable animals.

The ancient Greeks used liquorice root as a medicine for coughs and colds

How is liquorice made?

Trent Hamilton

■ Liquorice is actually a plant and the confectionary we eat is made from the sap extracted from its roots. Its distinctive flavour comes from a naturally sweet compound called glycyrrhizin, which is 50-times sweeter than sugar. To make liquorice, the dried roots are crushed and pulped into boiling water and the sap is extracted and dried into a golden-brown powder. It is then mixed with wheat flour, syrup and anise, dissolved in water and then boiled to create a dough. The dough is then compressed into moulds and left to dry into soft, chewy sweets. **JS**

What makes permanent marker permanent?

Billy Jones

■ Permanent marker ink contains compounds that are not soluble in water and are designed to stick to most surfaces. The ink is formed of a pigment, a solvent and a resin. Once the ink leaves the pen the solvent (usually alcohol) evaporates and the resin forms a glue-like film, allowing the pigment to adhere to even smooth, nonporous surfaces. Since it does not dissolve in water it can't be washed off easily. **AC**

Noble gases such as neon are the least reactive elements of them all

Why are some chemicals more reactive than others?

Trisha Lansdowne

An element's reactivity depends on how its electrons are arranged. Electrons orbit the atom's nucleus in layers called shells, with each shell holding up to a certain number of electrons. If an atom's outermost shell is full, it is less inclined to shed or gain an electron from another atom, making it very stable. Conversely, if the outer shell is occupied by just one solitary electron (ie sodium) this electron can readily be shared with another atom, making it highly reactive. Similarly, if the outer shell is just one electron short of being full (ie chlorine) it will tend to 'borrow' an electron from another atom. **AC**

How are tattoos removed?

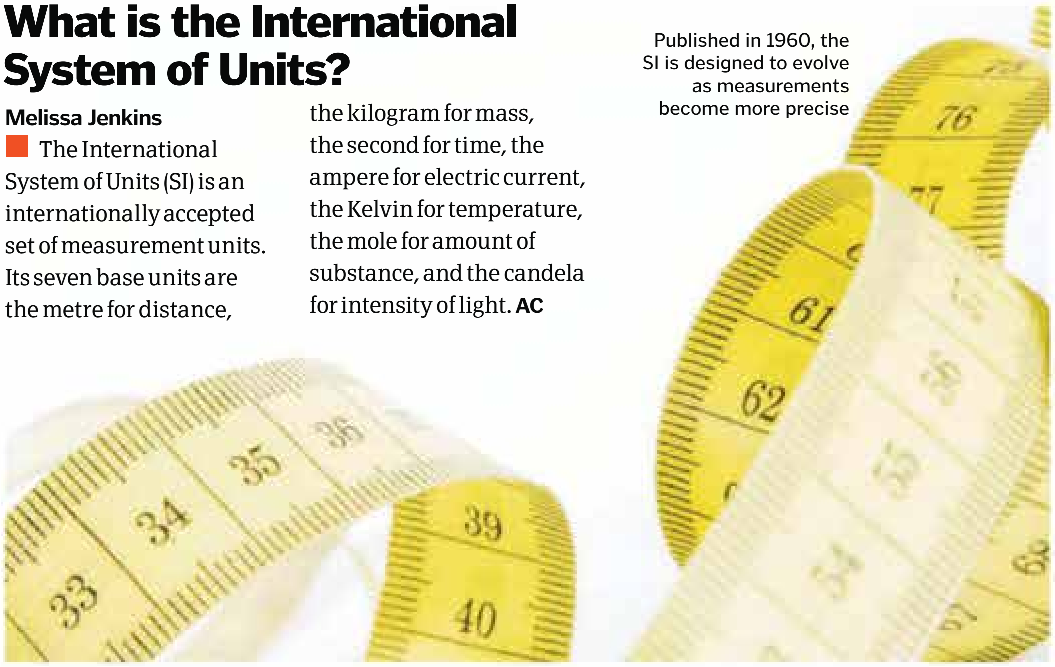
Rita Yates

Modern forms of tattoo removal use lasers that emit short pulses of intense light, which pass harmlessly through the top layers of the skin and are absorbed by the tattoo pigment. This causes the pigment to fragment into smaller particles, which are then absorbed into the bloodstream and removed by the body's immune system. Different types of lasers work on different pigment colours and will cause the tattoo to fade gradually over multiple sessions. **JS**

What is the International System of Units?

Melissa Jenkins

The International System of Units (SI) is an internationally accepted set of measurement units. Its seven base units are the metre for distance, the kilogram for mass, the second for time, the ampere for electric current, the Kelvin for temperature, the mole for amount of substance, and the candela for intensity of light. **AC**



Published in 1960, the SI is designed to evolve as measurements become more precise

What are storage heaters?

Storage heaters are electrical heaters that store thermal energy in ceramic bricks overnight — when electricity prices are cheaper — before releasing the energy as heat the following day. **AC**

What is the heaviest weight a human can lift?

In 2016, British weightlifter Eddie Hall became the first man ever to deadlift 500 kilograms, but it caused him to burst several blood vessels in his head and pass out. **JS**

Who invented piggy banks?

The piggy bank was invented by accident. During the Middle Ages people stored money in jars made from an orange-coloured clay called pygg, pronounced 'pug'. This later changed to 'pig', causing 19th-century potters to create jars shaped like pigs. **AC**

Why do minty things taste cold?

Mint oils contain menthol, which binds to TRPM8 receptors in your mouth. However, TRPM8 receptors also sense low temperatures, so when you eat mint, your brain receives a signal saying "That's cold!" **KS**

© Thinkstock; Pixabay; Getty

Methane-eating bacteria have been found in the Arctic and Antarctic permafrost

How could methane-eating bacteria help fight against global warming?

Lottie Fitzpatrick

Methane is a greenhouse gas. There's much less of it in the atmosphere than carbon dioxide, but it does an even better job of trapping heat around the Earth. It's released during the manufacture of fossil fuels, by farm animals and by the natural decay of organic material in landfills and sewer systems.

Methane-eating bacteria, also known as methanotrophs, use methane to make energy, pumping out carbon dioxide as a waste product. They already naturally filter methane gas in the Arctic and Antarctic, and scientists wonder whether they could help clean up the atmosphere on a larger scale. **LM**

Sudden changes in temperature or pressure can make a headache more likely

Can weather changes give you a headache?

Irini Arman

This may sound like an old wives' tale, but there is some evidence to suggest that rapid changes in the weather could leave your head throbbing. A large study conducted in the 2000s found that the risk of a headache rose by 7.5 per cent if the temperature increased by five degrees Celsius within 24 hours. A 6.6-millibar drop in pressure also increased the risk of a headache by six per cent. The reason why headaches and weather are linked in this way isn't clear, but researchers suggested that spikes in temperature might cause blood pressure to drop. **KS**

Is there a definition of room temperature?

No — room temperature varies across the world and different organisations set their own standards. The most common are 20 or 25 degrees Celsius. **LM**

Why is duct tape so strong?

Normal sticky tape is made from adhesives on a cellulose film, but duct tape has an extra layer. On the outside is a covering of waterproof polyethylene, while inside is a strip of strong rubber adhesive and in between there is a fabric mesh. **JS**

What protects the ISS against radiation?

An aluminium hull shields it from some radiation, but cosmic rays hitting the hull actually scatter secondary radiation into the ISS, which is partly absorbed by polyethylene shielding. The crew receive as much radiation in a day as they would in a year on Earth. **TL**

Do astronauts get taller in space?

Astronauts often grow a few centimetres in space, as their spine straightens out as the vertebrae move further apart in low gravity. However, they shrink back to normal size on their return to Earth. **TL**

How does a landline phone work?

Ben Sloane

Dialling a phone number sends an electrical signal through wires to a telephone exchange, telling it which number you dialled. The exchange then connects your phone line to the other person's phone line. When you speak into the phone, a microphone converts your words into electrical signals, which then travel through the network's wires to the other phone, where a speaker converts the electrical signals back into sound. Historically this was all done using electric wires, but today your words might also be converted into computer information so they can travel down fibre optic cables for parts of the journey. **TL**

Are tea bags biodegradable?

Teagan McKenna

Tea bags vary depending on the brand, but many contain small amounts of a plastic called polypropylene, which is used to seal the bags. While the paper bags and tea will decompose in a compost heap, tiny fibres of this plastic will be left behind. **KS**

What was the War of the Roses?

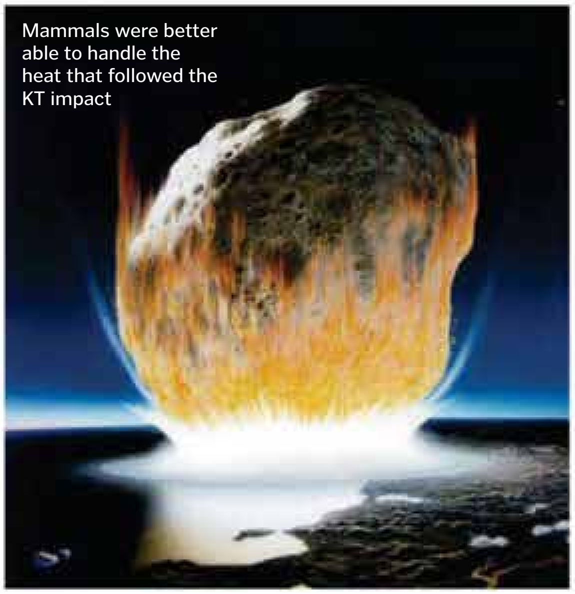
Chantelle Newton

The Wars of the Roses were a series of civil wars between 1455 and 1487. Over three decades the rival families of the House of Lancaster and the House of York fought for control of the English throne. Each side supposedly used a different colour rose as its symbol: York a white rose, Lancaster a red rose. However, the conflict probably wasn't named the 'Wars of the Roses' until later. **TL**

Who invented bubble wrap?

Austin Riley

Bubble wrap was invented by Alfred Fielding and Marc Chavannes in 1957 — but the pair hadn't set out to create packaging. Instead, the material was invented as a type of wallpaper, with air bubbles trapped between two laminated sheets. It wasn't popular with interior designers, but its lightweight, cushioning properties made it perfect for packaging. Fielding and Chavannes founded the Sealed Air Company in 1960 and have since expanded their portfolio to include envelopes, food packaging and medical products. **KS**



Mammals were better able to handle the heat that followed the KT impact

How did some mammals survive the KT extinction?

Flora Ames

Mammals were generally pretty small when dinosaurs ruled the Earth; they lived in water or underground and they were adapted to eat a variety of foods. When the asteroid struck, the Earth heated rapidly, plant life died away and large animals were left hot and exposed with nothing to eat. Mammals were sheltered; they could regulate their body temperature; and they could eat insects, helping them to thrive in these new, challenging conditions. **LM**

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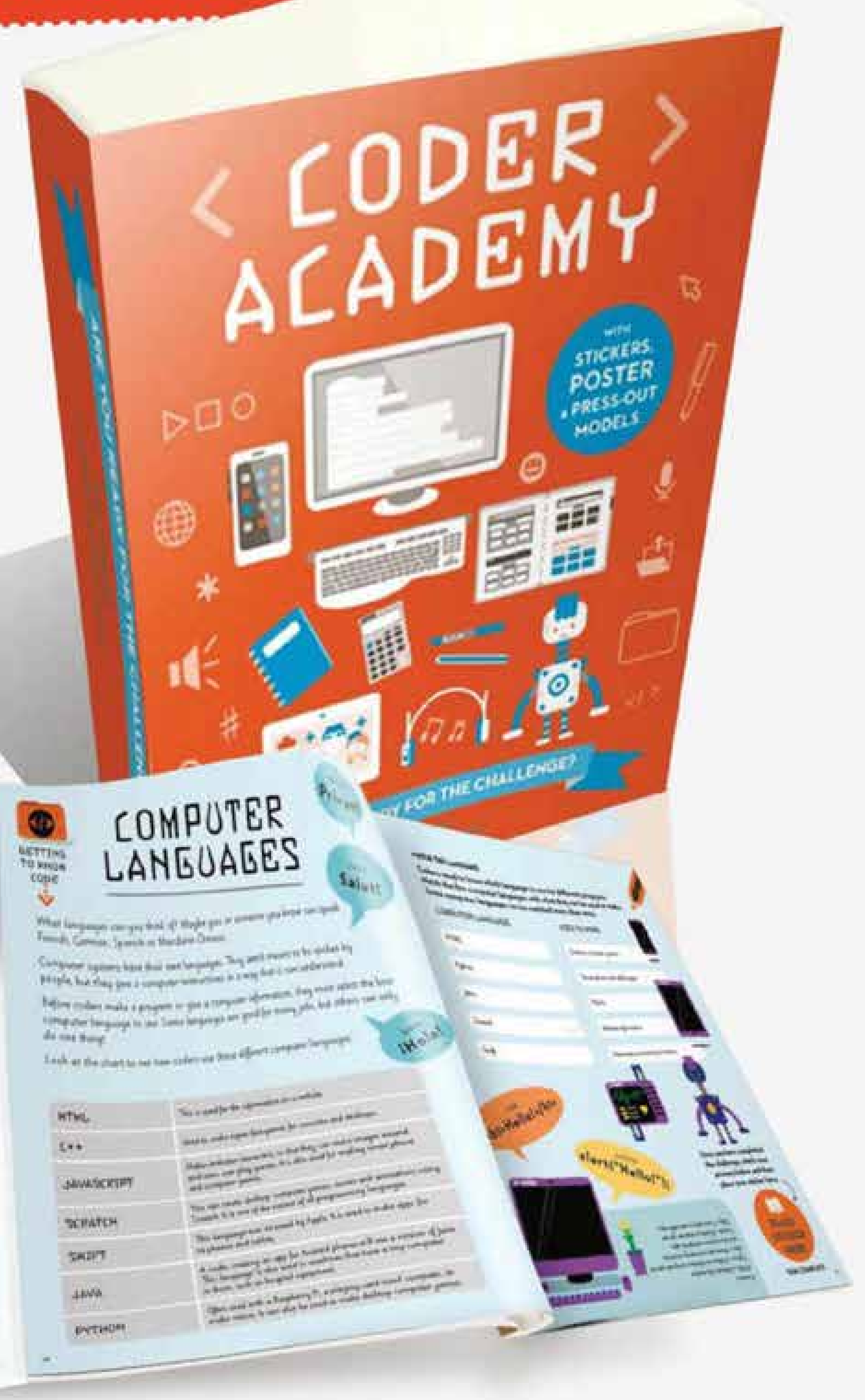
BOOK REVIEWS

The latest releases for curious minds



Coder Academy

A playful way of teaching kids to code

- Author: **Sean McManus**
- Publisher: **Ivy Kids**
- Price: **£9.99 (approx. $13)**
- Release date: **Out now**

You only have to dig into Microsoft founder Bill Gates' past a little to discover that he was an accomplished coder at a young age. And although he's now used his talent to help fill the world with accessible computer software, the need for youngsters to become coder-savvy is as important as ever.

For those seeking to inspire the next generation to go down this important path, *Coder Academy* would make a most welcome addition to the bookshelf. From accomplished author Sean McManus comes the latest in the *Academy* series: a collection of books that encourage readers to learn about a topic through interactive games and challenges. *Coder Academy* achieves this goal in fine form, transforming a typically dry subject into something much more palatable through informative and enjoyable activities.

The introductory tasks are simple and help readers understand the fundamental premise of coding. McManus uses these pages to teach the importance of writing clear and concise instructions, covering the basics of binary code and introducing the array of coding languages all in engaging ways. And in later pages readers graduate onto their computers for coding computer games, animating images, writing music and building web pages, using the text and informative graphics as a guide.

When striving to make a topic as complex as coding accessible and digestible for a young audience, it's inevitable that some needed detail is omitted in various sections. But the sacrifice is warranted in this case, as body text is replaced with useful tables and diagrams to help simplify the task at hand. These elements, added to the attractive colour scheme and border images, help to make the book appear as inviting as possible, which is quite an accomplishment for such a potentially intimidating topic.

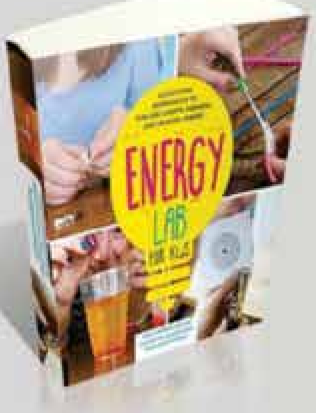
Coder Academy strives to both inform and entertain in equal measure and incorporates much more than just text to keep its readers turning through its pages. After completing a page's task, readers can mark their success with a sticker, and at the end of each section they'll find a certificate waiting for their signature.

These small rewards are sure to encourage our future coders to return for the next chapter and may even plant the seed for a lifetime passion for — or even a career in — the exciting world of computer coding.

★★★★★

Energy Lab for Kids

Energising interest in science from childhood



- Author: **Emily Hawbaker**
- Publisher: **Quarry Books**
- Price: **£14.99 / $22.99**
- Release date: **Out now**

Getting kids excited about science is something of a speciality for science educator Emily Hawbaker, and that shines through in *Energy Lab for Kids*. This photo-rich and well-designed book contains 40 different homemade science experiments aimed at kids from primary age onwards. Each lab experiment focuses on a different aspect of energy, be it steam, solar, electric, wind or even chemical — nothing dangerous, don't worry — most of which are easily done at home, some even on your own (but where's the fun in that?).

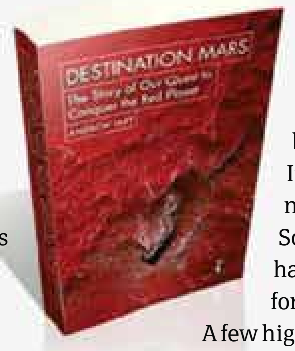
Throughout the book Hawbaker does an excellent job of combining an active, visually engaging experiment with real-world learning on energy, explaining how it works and how we can explore and exploit it to enrich our world.

While some of the experiments may appear on the dull side, those are relatively few and far between, and the instructions for each one are mostly crystal-clear and easy to follow. It's also a great way for children and their parents to bond over something that's both fun and practical.

★★★★☆

Destination Mars — The Story of Our Quest to Conquer the Red Planet

Exploring the cutting-edge of science and technology



- Author: **Andrew May**
- Publisher: **Icon Books**
- Price: **£7.99 / $12.95**
- Release date: **Out now**

After Ridley Scott's Mars-based survival drama *The Martian* took off worldwide, our fascination with Mars has been rekindled. Astrophysicist-turned-author Andrew May expertly plays on this enthusiasm with a unique blend of science and humour.

In his preface, May breaks down our relationship with Mars throughout history. In science fiction, the most popular portrayals of the Red Planet involve an inhospitable but habitable environment with intelligent and hostile aliens seeking to invade Earth. May, on the other hand, provides indisputable evidence that life on Mars died out billions of years ago. If our closest neighbour in the Solar System does harbour life, it's in the form of bacteria.

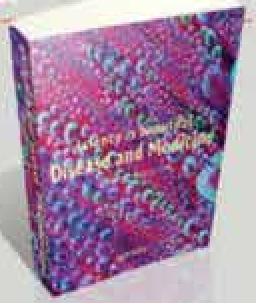
A few highlights include May's exploration of how we get to Mars and precisely why this is so complex — apparently *The Martian* is fairly accurate on that score. He also analyses the new Space Race between NASA and Elon Musk's company SpaceX.

This is a must-read for anyone seeking to understand the real scientific possibilities regarding a future manned mission.

★★★★★

Science is Beautiful: Disease and Medicine Under the Microscope

The beauty and the battles beneath the microscope



- Author: **Colin Salter**
- Publisher: **Batsford**
- Price: **£20 / $35**
- Release date: **Out now**

Science-related literature often gets caught up in the verbose, detailing the minutiae of scientific theory, often forgetting the sheer magnificence of what it's dealing with. Thankfully, Colin Salter has turned this model upside down.

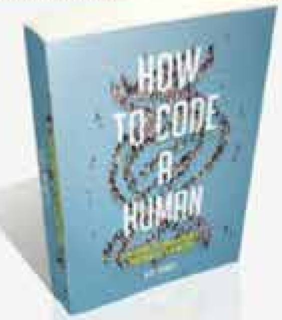
In the time-honoured tradition of classic coffee table books, the beautifully packaged *Science is Beautiful* leads with large, detailed and consistently magnificent photographs of diseases — including some of the most fatal known to humans — and the medicine used to battle them, all taken through the lens of high-resolution microscopes.

Accompanying each image is a description of what it contains, often with a surface explanation of the scientific elements at play in the picture. As if the images don't already blur the line between science and art enough, these texts are more art gallery level than encyclopedic in depth, but the unique and entrancing presentation should compel any reader to look up more than one of the creations in the book. And perhaps unsurprisingly, it's often the most dangerous ones that look the most enchanting.

★★★★★

How to Code a Human

Exploring the DNA blueprints that make us who we are



- Author: **Kat Arney**
- Publisher: **Andre Deutsch Ltd**
- Price: **£16.99 / $24.95**
- Release date: **Out now**

The premise behind *How to Code a Human* is intriguing — how does our DNA shape us? Dr Kat Arney, who has a PhD in developmental genetics from Cambridge, is clearly an expert in the subject. The trouble is, she sometimes assumes the reader is too.

Arney's introduction is promising as she highlights the complexity of DNA and how a single piece of code can alter our entire personality. We are also guided through scientific advancements in the field of genetics and how our understanding of DNA is constantly evolving. A particular highpoint is 'Our Genetic Journey', where Arney details how our genes have shifted throughout time and turned us into the complex beings we are now.

However, this book is occasionally hard to follow for those not familiar with the subject matter. There is a lot of focus on the science and not enough of the 'human element'.

How to Code a Human emphasises the significance of our DNA and is still well worth a read for those who have a grounding in biology or genetics. For those that do not, this may prove a challenging read.

★★★☆☆

BRAIN GYM

GIVE YOUR BRAIN A PUZZLE WORKOUT

Wordsearch

B	F	X	S	D	P	G	X	H	T	I	T	B	Y	A
G	E	I	U	E	L	L	H	U	S	E	P	Y	Q	E
H	L	E	N	L	A	I	E	M	E	S	M	R	E	T
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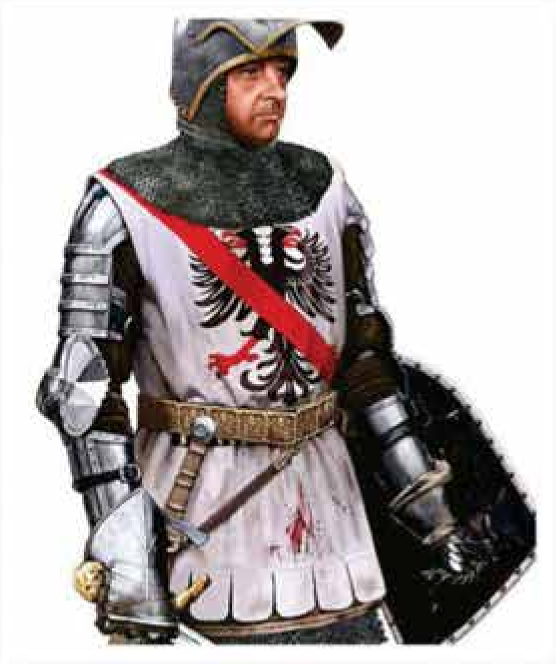
N	I	E	L	X	I	M	O	M	R	E	H	T	E	U
E	D	I	C	T	A	T	O	R	K	E	L	I	A	J

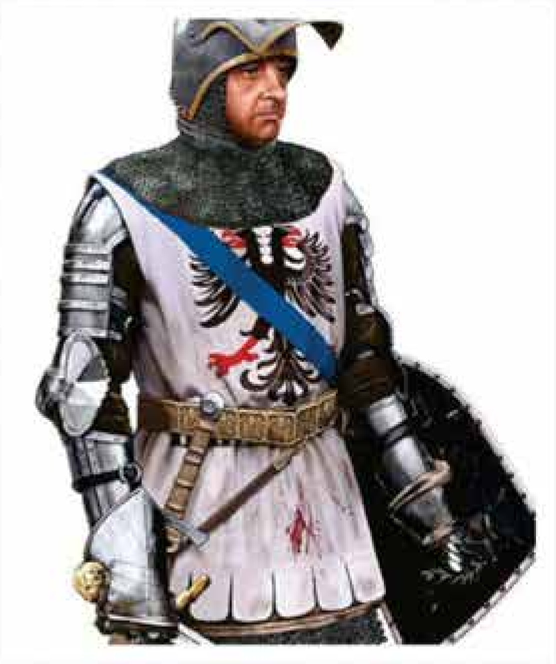
FIND THE FOLLOWING WORDS…

BEES
DELOREAN
DICTATOR
EDINBURGH
ELECTROLYTE
ENGINE
GOLF
GUILD
HELACELLS
HUMMINGBIRD
HYDROFOIL
IMMUNE
JURASSICCOAST
ORRERY
PLANETARY
SMARTHOME
SUNSPOT
THERMOMIX
WILDWEST

Spot the difference

See if you can find all six changes we've made to the image on the right





Quick-fire questions

Q1 What is the average acceleration due to gravity on Earth?

○ 7.1m/s^2 ○ 2.4m/s^2

○ 19m/s^2 ○ 9.8m/s^2

Q2 Which sport uses the terms 'birdie' and 'bogey'?

○ Chess ○ Tennis

○ Golf ○ Archery

Q3 Where does Edinburgh Castle sit?

○ Castle Rock ○ Dad Rock

○ Casterly Rock ○ Scot Rock

Q4 Nerve impulses involve potentials

○ Reaching ○ Impulse

○ Action ○ Nervous

Q5 Which traffic light colours can appear at the same time?

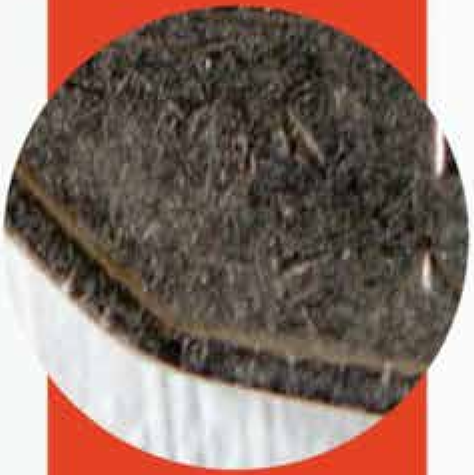
○ Red and green ○ Amber and green

○ Red and amber ○ None

Q6 How is William H Bonney better known?

A

What is it?



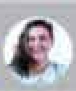
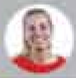
A ____________________

Sudoku

Complete the grid so that each row, column and 3x3 box contains the numbers 1 to 9. See if you can beat the team!

		4	9	3	8			6
	8	6				9	7	3
1			6		2		5	8
	4			8	6	2	3	9
	3	9	2	5	4		1	
			7		3		8	
3	1	8	5	6		7	4	2
9		2		4	7	3	6	1
4	6	7		2	1		9	5

BEAT THE TEAM…

1		**Jackie**	01m 50s
2		**Charlie**	01m 59s
3		**Laurie**	02m 24s
4		**Charlie**	03m 17s
5		**Duncan**	03m 33s

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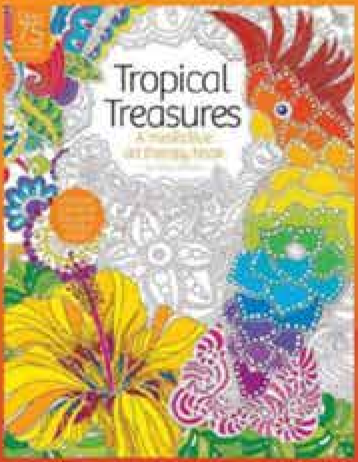

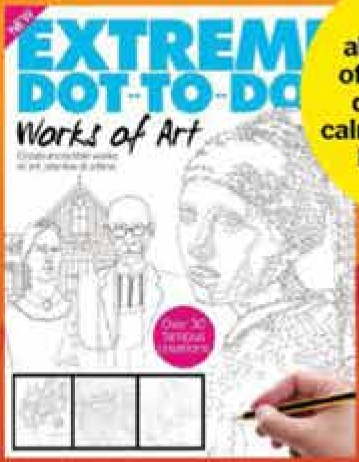

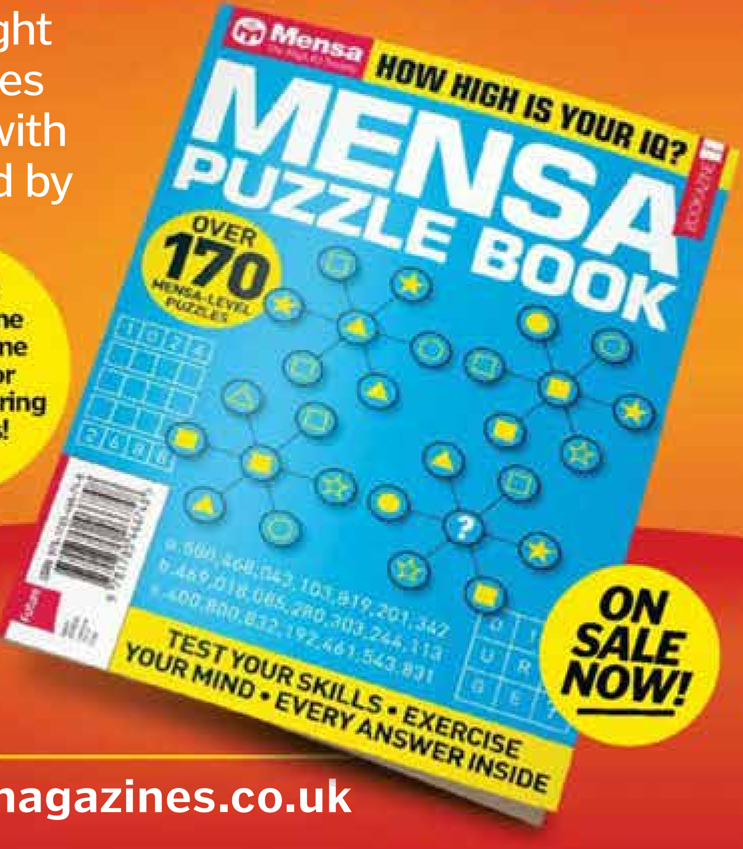
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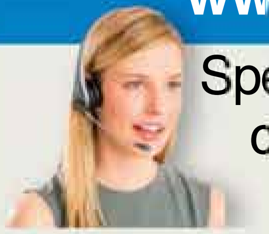

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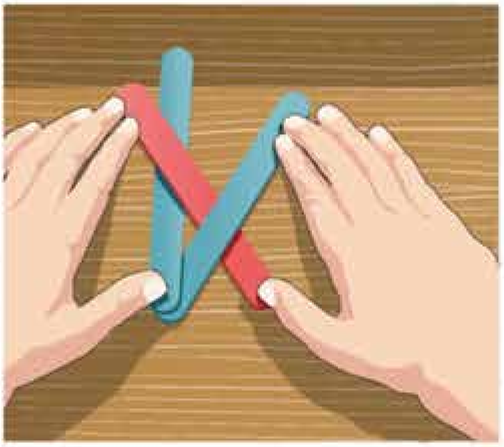
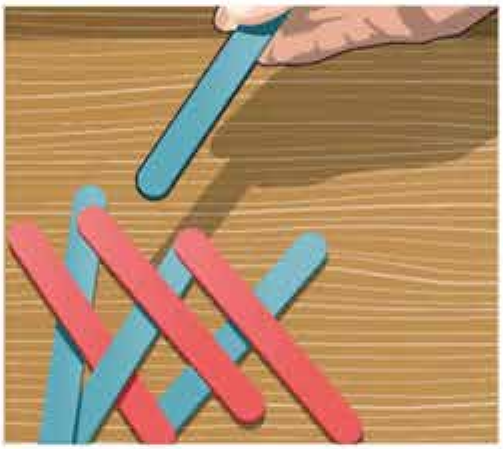
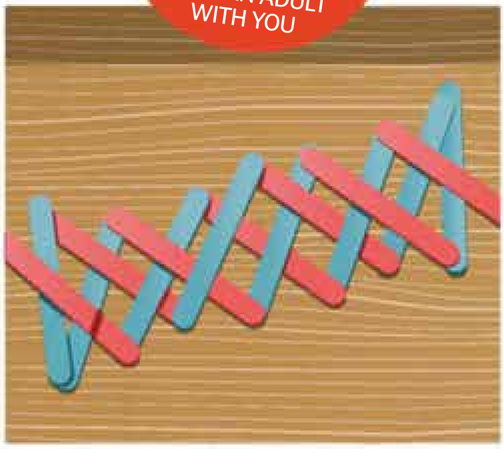
DON'T DO IT ALONE

IF YOU'RE UNDER 18, MAKE SURE YOU HAVE AN ADULT WITH YOU







1 Collect your sticks

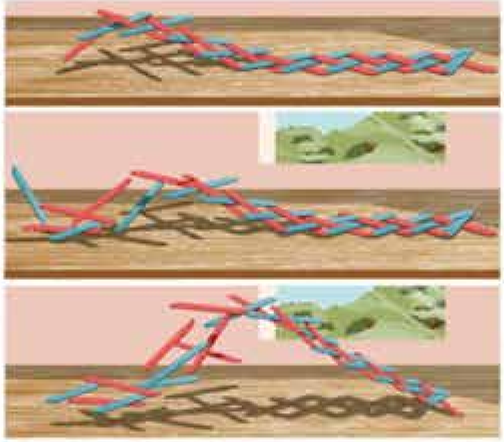
For this nifty experiment all you'll need is a set of jumbo lollipop sticks. Preferably they should be two different colours — it'll help when you're weaving the pattern. But this isn't a requirement. If you don't fancy munching your way through a pile of lollies you can simply buy a stack of crafting lollipop sticks, which handily come in a variety of colours too.

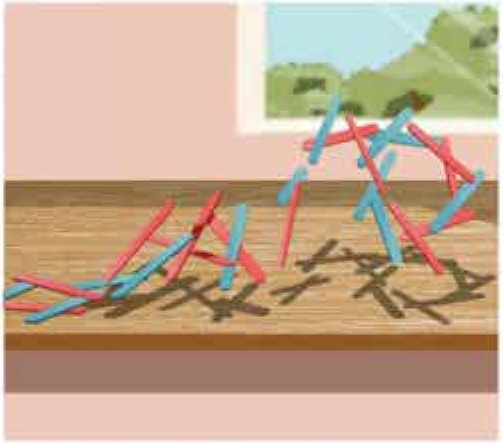
2 Begin the pattern

To start, arrange two sticks in a V shape then thread in a third stick diagonally across the V near its base. This stick should rest above the stick on the left of the V and go underneath the stick on the right. The next stick we add — the tip of which will be placed touching the tip of the left-side V stick — will do the opposite, by sitting under the left-hand stick and going over the right.

3 Finish weaving

Continue in this same pattern by adding a stick that sits below and forms a new V with the third stick and goes over the top of the fourth. You can now repeat this weave to build a structure as long as your supplies allow, but make sure you form an X with the final stick when you're done. You'll need to use at least 15 sticks, and the longer the final product is the better the result will be!





4 Ride the wave

By bending all those sticks to weave them together you've successfully created a lot of tension. Now we're going to release it! With your structure laid on a flat surface, pull out the first stick that formed part of your original V. Some of the sticks will push down one after another as they're released, forcing the weave into the air like a wave!

5 Enjoy the explosion

The longer your structure is, the more pronounced the 'ripple' of the wave will be as the sticks leap into the air while the ripple moves towards the end of the weave. Once the movement reaches the end, the sticks will fly out in all directions! This is because the energy doesn't have a path of least resistance to follow, so instead it will push out everywhere.

> "Once the movement ends the sticks will fly out everywhere!"

In summary...

When you bend something you store energy in the object. Lollipop sticks that are weaved together in a stable structure and held in bent positions are able to keep this stored energy. But when the structure is no longer able to maintain the tension the energy is released suddenly in the form of movement.

Disclaimer: Neither Future Publishing nor its employees can accept liability for any adverse effects experienced after carrying out these projects. Always take care when handling potentially hazardous equipment or when working with electronics and follow the manufacturer's instructions.

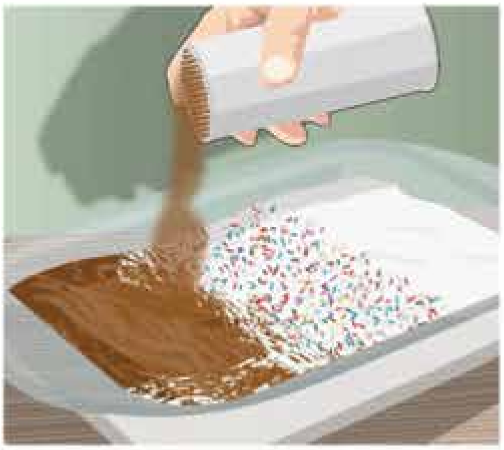
Make impact craters

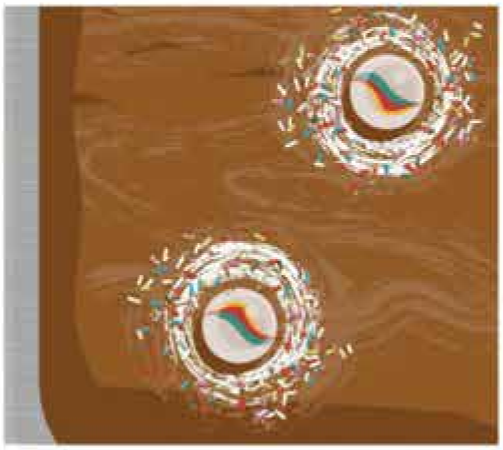
Understand our Moon a little better using flour and cocoa powder

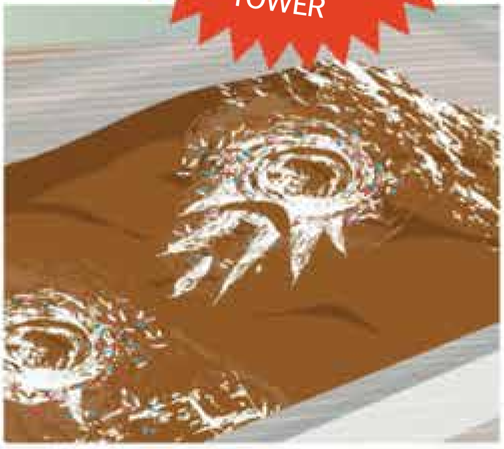
NEXT ISSUE

MAKE SYCAMORE HELICOPTERS

BUILD A SOLAR TOWER







1 Create the surface

Have you ever looked up at our celestial companion, gazed at its many giant craters, and wondered why they all look so different? To answer this question grab yourself a baking tray with raised edges, flour, spherical coloured sprinkles, cocoa powder, a sieve and a few marbles. Fill the baking tray with an even layer of flour two centimetres high, then cover this with sprinkles. Now use the sieve to add a cocoa layer.

2 Drop your asteroids

Now it's time to bombard the surface with marbles! Drop the spheres from different heights, and make sure to use a variety of different sized marbles if you have them. Notice anything about the resultant impact craters? Try dropping the marbles softly onto the powder at different angles and compare the shapes of the impact craters to the ones made from marbles dropped from directly above.

3 Look and learn

Although this experiment is simple it can teach us a lot. Is there any flour in or around your impact craters? If so, we've just seen how a colliding object can kick up material from deep underground. And did any of the impacts blow powder out of the tray? Scientists think something like this formed our Moon — an impactor hit Earth, blowing lots of matter far away that later combined to form our satellite.

> "Drop the spheres from different heights and angles"

In summary…

The Moon has a very destructive past; during the early Solar System it collided with many asteroids and meteors that permanently dented its surface. The marbles and powder reveal how the mass, speed, angle and size of these objects determined the shapes of the craters.

© Illustrations by Ed Crooks

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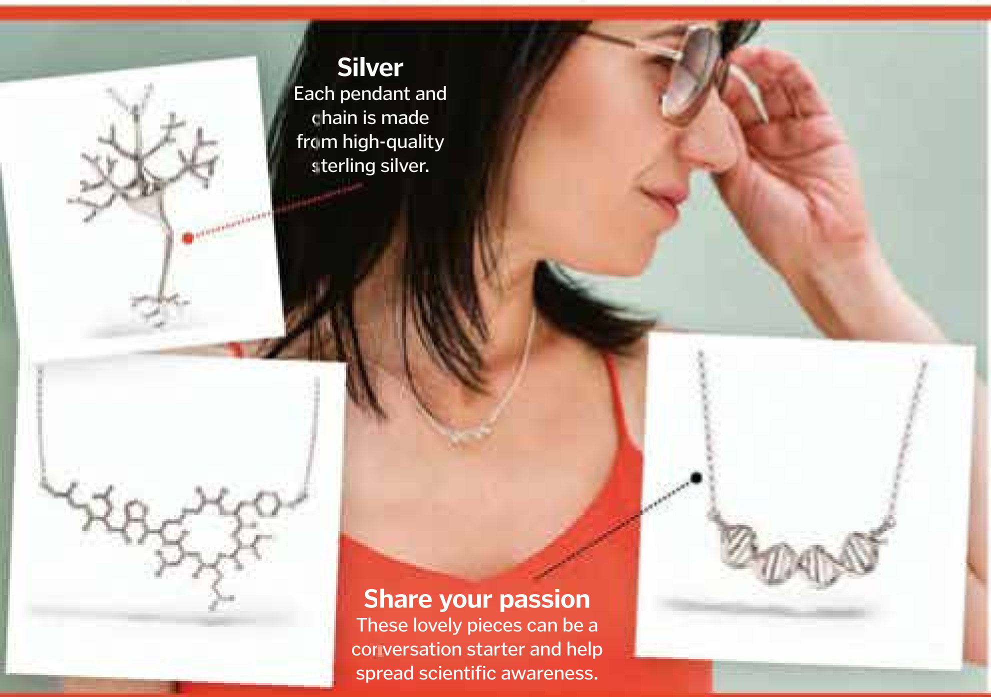
A trio of science-inspired pendants worth £295



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These lovely pieces can be a conversation starter and help spread scientific awareness.

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Amazon's smart home devices use which artificially intelligent personal assistant?

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As the probe finishes its exploration of the Saturnian system, discover the amazing tech behind a decade of discoveries by the Cassini orbiter and Huygens probe

Letter of the Month

Revenge in the name of knowledge

Dear **HIW**,
My brother collects **HIW** and doesn't always let me read it. When he is out I like to take it and read it anyway. This is my favourite issue. If this gets published he will be so annoyed... he he he.
Jessica Hall

We love this photo Jessica! And we approve of your actions — don't let anyone or anything stand between you and knowledge!

We hope this encourages your brother to share his copies of HIW a little more often... the same goes for any other siblings out there who are protective of their collections. Science should be shared! 😉

Not so different

Dear **HIW**,
I love your magazine, I have been reading it for a couple of years now. Recently I heard that we share 99 per cent of our DNA with chimpanzees, so what is it that makes us different from them? I really hope you can answer my question.
Zac Lovat

Hi Zac, that's a very interesting question. We do indeed share the majority of our DNA with chimpanzees, and they are our closest living relatives.

That differing one per cent is made up of 15 million units called bases, which can mutate in several different ways and alter genes.

Analysing all these differences between human and chimp DNA takes a very long time, but research so far has revealed several genetic differences. A unique variation in a sequence of our genome known as HAR1 is thought to play a role in the development of the human brain.

Another example is that hominids have a variation in the gene known as FOXP2, which is thought to be linked to our ability to speak.

Just one per cent of a genome has led to some big differences between us and apes

Dangerous creatures

Dear **HIW**,
What is the deadliest European animal?
Oliver Livingston

That's a good question, Oliver. There aren't many statistics on European fatalities caused by animals. It is difficult to say exactly which one is the deadliest, but there are quite a few different candidates.

It might surprise you to learn that domesticated animals are some of the most common causes of animal-related fatalities. In the UK, dogs are responsible for around two deaths a year, while cows cause around five deaths annually.

Allergies to insect stings can also be deadly, with approximately five people per year in the UK dying after being stung by wasps, bees or hornets.

In Europe, fatalities due to animal attacks are rare. Many wild animals will avoid human contact unless they are starving, diseased or provoked. That said, deaths caused by wild boars, wolves, brown bears and polar bears are not unheard of in some parts of Europe.

Cows are the most deadly large animals in Britain

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What's happening on...

social media?

Here's the latest from some of our favourite accounts...

"Check out the interview with Guide Dog Trainer, Sam in @HowItWorksmag 's Dogs with Jobs feature! #pupswithapurpose #lifechangers"

@GuideDogs_Comms

"Farewell Cassini, how far you've come. On this eve, in fiery death, Saturn & you are one. VIP (Vaporize In Peace): 2004-2017"

@neiltyson

"Rock on, #boron! Finding this element gives another clue that life could have once arisen on #Mars"

@MarsCuriosity

"New DNA analyses has confirmed that a resplendent Viking warrior grave belonged to a woman"

@NatGeo

"Tesla Semi truck unveil & test ride tentatively scheduled for Oct 26th in Hawthorne. Worth seeing this beast in person. It's unreal."

@elonmusk

"I think the world has never been better—more peaceful, prosperous, safe, or just. And I'm on a mission to prove it."

@BillGates

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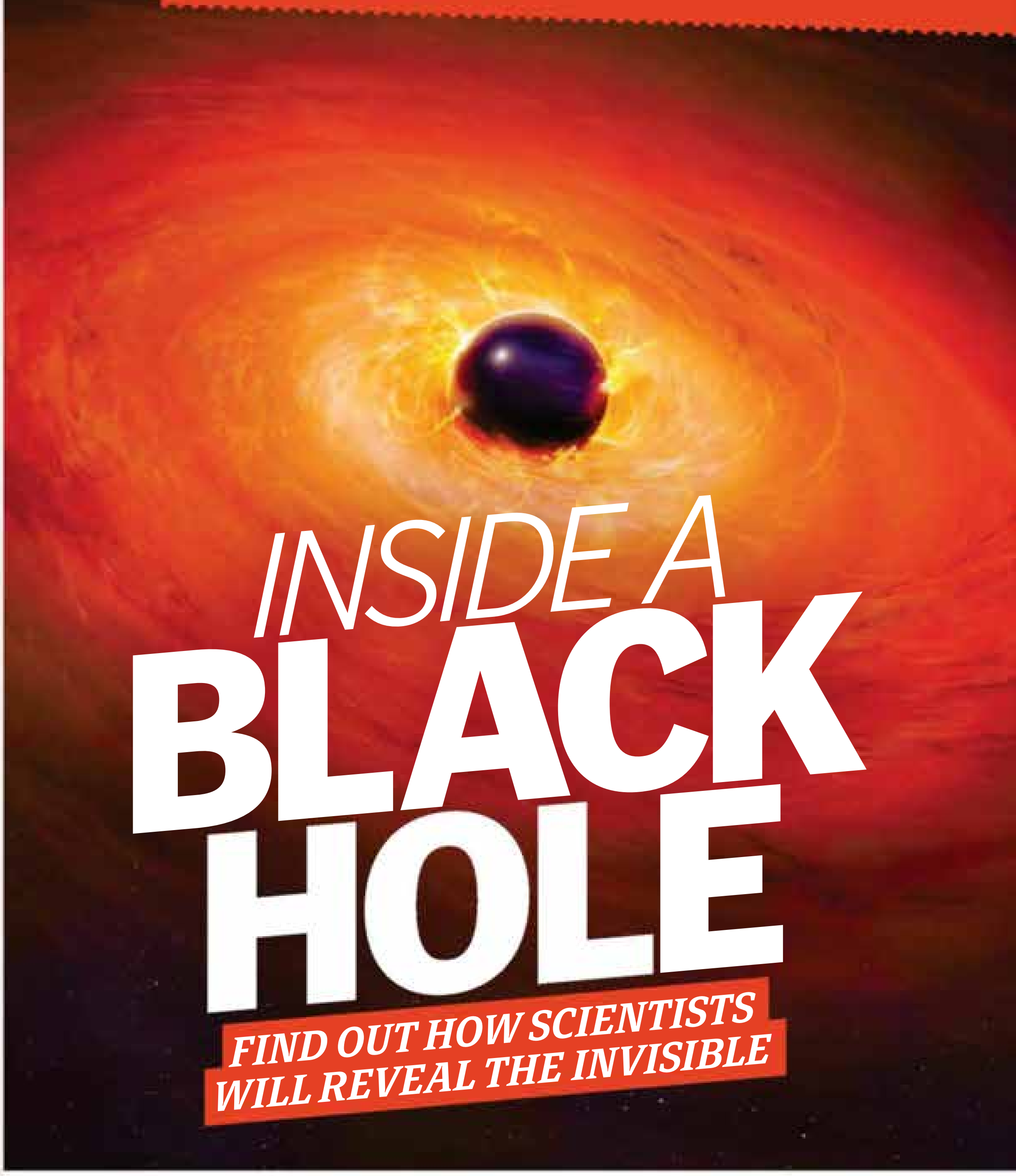

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